STRATEGIC OVERVIEW OF RIPARIAN AND AQUATIC CONDITION OF THE SOUTH SASKATCHEWAN RIVER BASIN

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REPORT ON

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EXECUTIVE SUMMARY

In July 2002, Alberta Environment (AENV) commissioned Golder Associates Ltd. (Golder) to conduct a qualitative "Strategic Overview of Riparian and Aquatic Condition" (SORAC) of the mainstem rivers of the South Saskatchewan River Basin (SSRB) in southern Alberta. The purpose of this initiative was to derive a sense of the integrity of the aquatic ecosystem. This ecological status report reflects the integrated views of scientists and managers working in the SSRB without any specific data review or analysis. The report is an assessment based solely on the opinions of a 'Best Judgment Panel' (BJP) (membership can be found in Appendix V of the main text) and does not involve a review of any quantitative data or previously undertaken analyses.

The report provides a qualitative estimate of the relative ecological status and indicates the sustainability of current conditions and practices within individual reaches of each sub-basin in the SSRB. Decision makers may use this report to improve their adaptive management strategy for this large, multi-use river system in order to maintain its ecological integrity.

Red Deer River Sub-basin Assessment

The BJP thought the reaches of the Red Deer River were in generally better condition than those of the Bow or the Oldman rivers. The reasons given were the relatively natural flow and the relatively low quantity of chemical and organic contaminants input to the system. Gleniffer Lake, which was created by the Dickson Dam (located at the upstream end of reach RD-07) is the only major impoundment on the mainstem of the Red Deer River. The BJP judged the reach above Gleniffer Lake (RD-08) the least impacted reach based on its lack of development, the relatively natural state of the mostly forested watershed and the natural flow regime (main text: Figure 2). The middle reaches (RD-05 and RD-06), which are below the City of Red Deer and receive inflows from the Medicine and Blindman rivers, were judged by the BJP to be in the worst ecological condition among the reaches of the Red Deer River sub-basin. All reaches except RD-08 were considered to have a declining 5- to 10-year trend. RD-08 was considered stable. The effluent from municipal treatment facilities was considered a major factor in this declining trend, particularly as it relates to water quality.

South Saskatchewan River Sub-basin Assessment

Generally, the BJP respondents thought the reaches of the South Saskatchewan River were in better condition than the lower reaches of either the Bow or the Oldman rivers. The reasons given were the increased flow and the ability of one of the sub-basins to provide water when the other might be in a period of low discharge.

Bow River Sub-basin Assessment

The lowest reach of the Bow River (BW-01) is warm (in summer), eutrophic, and shallow due to upstream water extractions and, because of these attributes, the ecological condition was judged by the BJP to be among the worst of all river reaches in the SSRB (main text: Figure 3). Reach BW-03 was judged by the panel to be enhanced by the re-regulated flows from Bearspaw Dam and flows from the Highwood River (175 km in length). Flows in BW-03 and downstream reaches are enhanced during winter months due to releases from upstream hydroelectric plants. This enhanced flow coupled with the nutrient load from the City of Calgary has resulted in a productive sport fishery in this region of the Bow River. All the reaches were considered to be in a stable 5- to 10-year trend except for BW-01, which is considered to be declining even though it is considered degraded at the present time. A general concern was expressed related to habitat connectivity and the effect of dams and diversions on fish movement. On the positive side, water quality was seen as improving as a result of upgraded municipal treatment facilities.

Oldman River Sub-basin Assessment

Although there was much concern expressed about the ecological integrity of the Oldman system, the BJP rated it as only moderately impacted or better throughout (main text: Figure 4). The main concerns related to the major dam and diversion and their impact on fish habitat connectivity, and the effects of reduced flooding on riparian diversity. The 5- to 10-year trends were considered stable for all reaches and there was a general feeling the water quality was improving or had improved due to the upgrading of the Lethbridge sewage treatment facilities and the enhanced flows during low flow periods.

Southern Tributaries of the Oldman River Sub-basin Assessment

Among the reaches of the southern tributaries of the Oldman River, the lower two reaches of the St. Mary River (SM-01 and SM-02) are considered degraded. These two reaches and the lowest reach of the Bow River were the only reaches in the SSRB that were given a degraded classification (main text: Figure 5). At the other end of the spectrum, the upper (reference) reach of the Waterton River (WT-03) was considered Unchanged/Recovered, the only reach within the SSRB study area to achieve this ranking. The lower two reaches of the Waterton River, and the lowest reach of the Belly River, were all considered heavily impacted. The lower two reaches of both the St. Mary and Belly rivers were considered to be in a declining trend, while the remaining reaches of these rivers were evaluated as stable. The Waterton River was considered stable except for reach WT - 02, which was declining.

Improving the Ecological Assessment Approach

The key to developing an improved assessment approach in the future will be incorporating relevant quantitative data, and analyses of those data, to provide the basis for a more rigorous evaluation of ecological status. For some types of information (*e.g.*, hydrology) extensive data sets are already available. For other types of information (*e.g.*, benthic invertebrates, fish populations, and riparian communities) long-term monitoring programs will be required to collect quantitative data.

Further development and improvement of the ecological condition assessment approach will need to be carefully planned. In order to provide a more comprehensive and defensible assessment approach, it will be necessary to incorporate various quantitative analyses that will have to be supported by monitoring programs to collect the appropriate data. Both the data collection and analysis phases can be quite costly and time consuming. It is therefore important to undertake further development of the assessment method with careful consideration of the feasibility of any proposed enhancements to the approach.

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In July 2002, Alberta Environment (AENV) commissioned Golder Associates Ltd. (Golder) to conduct a qualitative "Strategic Overview of Riparian and Aquatic Condition" (SORAC) of the mainstem rivers of the South Saskatchewan River Basin (SSRB) in southern Alberta. The purpose of this initiative was to derive a sense of the integrity of the aquatic ecosystem. This ecological status report reflects the integrated views of scientists and managers working in the SSRB without any specific data review or analysis. The report is an assessment based solely on the opinions of a 'Best Judgment Panel' (BJP) (Appendix V) and does not involve a review of any quantitative data or previously undertaken analyses (Appendix II and Appendix IX). The panel was selected by AENV staff to reflect the diverse fields of expertise that must be taken into account in any ecosystem assessment. The expert opinions are the integration of years of work experience and training. These opinions will eventually need to be supported by defensible data to enable the identification of the many sources of stress and their relative importance in the system. Identification of these stressors will aid in targeting key management issues (see AENV (undated(a)) and (undated(b)) for a public review of the principles of water management).

The report provides a qualitative estimate of the relative ecological status and indicates the sustainability of current conditions and practices within individual reaches of each sub-basin in the SSRB. Decision makers may use this report to improve their adaptive management strategy for this large, multi-use river system in order to maintain its ecological integrity.

2. INTRODUCTION

Relative to their size, rivers and their associated riparian zones comprise one of the most biologically diverse and heavily used ecosystems (Innis *et al.* 2000); unfortunately, they are also subjected to a greater diversity of human use and abuse than any other biotope (Boon 2000). Water is always important, and more so in dry lands such as the south-western Canadian prairies. The SSRB (Figure 1) has undergone detailed study and planning due to its importance to agriculture, industry, and urban growth in southern Alberta. Although much research has been carried out on the SSRB, data gaps still exist and the existing data may not have been managed in such a manner that permits easy access and interpretation. Because of the time and resources that would have been required to fill the data gaps and review existing information, it was decided the most efficient approach would be to form a BJP to review the status of the aquatic ecosystem. The panel members integrated their combined knowledge and experience into this assessment of ecological condition.

The international instream flow council has recently released a book entitled "Instream Flows for Riverine Resource Stewardship" (Annear *et al.* 2002). The instream flow council's extensive review of the sciences of river ecology, hydrology, limnology, geomorphology, and their inter-relations provides an up to date synopsis of the current understanding of this technology and how it functions in various jurisdictions using different approaches.

The SORAC report relates to the mainstem rivers, associated riparian zones and wetlands, and watershed upland ecosystems of the SSRB in Alberta. The objectives of the investigation are to:

- record the current BJP views of the environmental conditions and any associated trends of the SSRB on a reach basis;
- identify the key issues leading to the ecological assessment by sub-basin and by reach;
- identify the key analytical techniques and data necessary to enable such an assessment to be made quantitative and defensible;
- identify knowledge and/or data gaps; and,
- recommend future research and development directions.

Note: The map on the following page (Figure 1) has been presented in 11" x 17" format.

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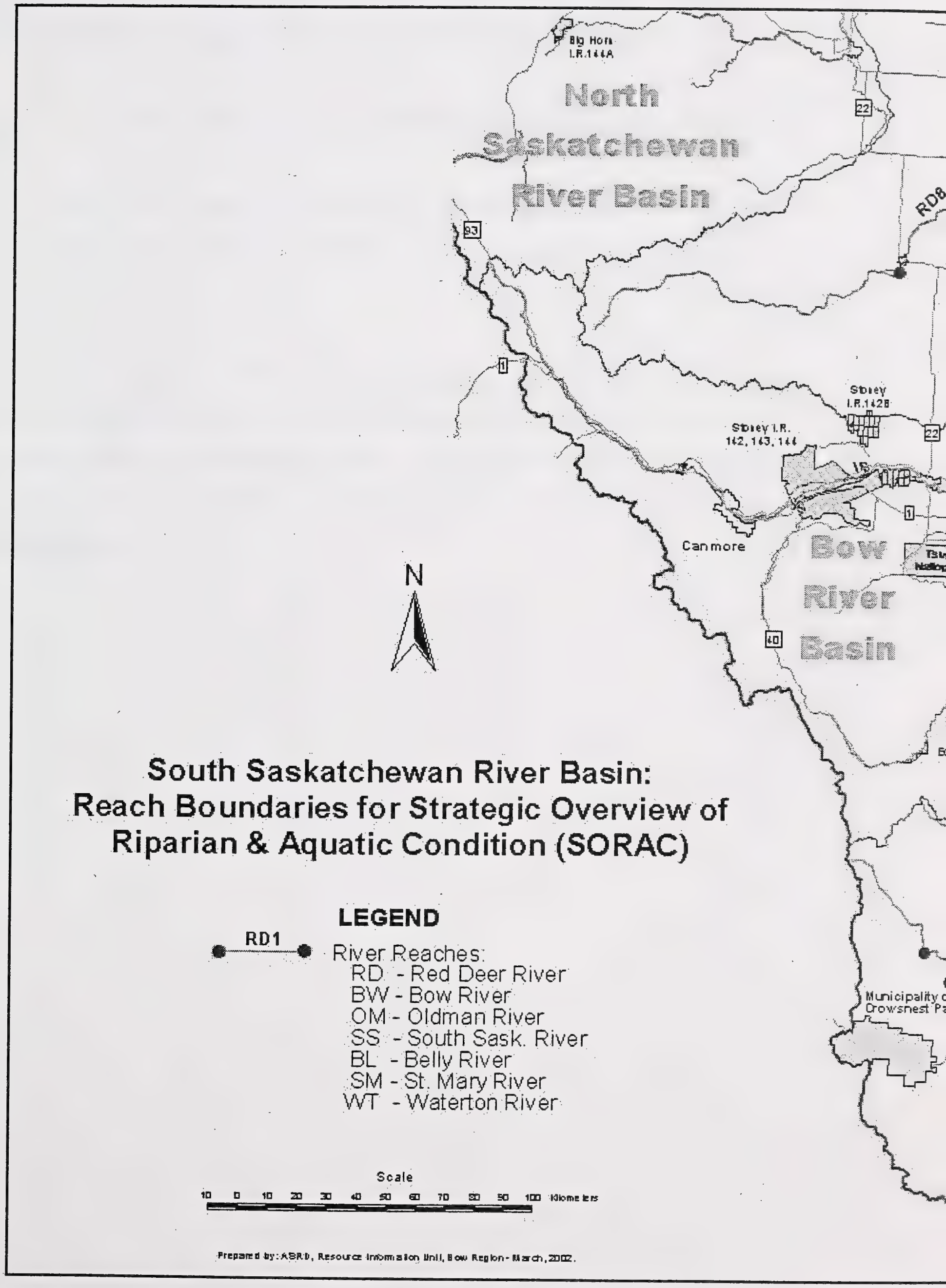
The South Saskatchewan River Basin and the Reach B



(Map prepared and made available by Resource Information Unit, ASRD, Calgary, Alberta.)

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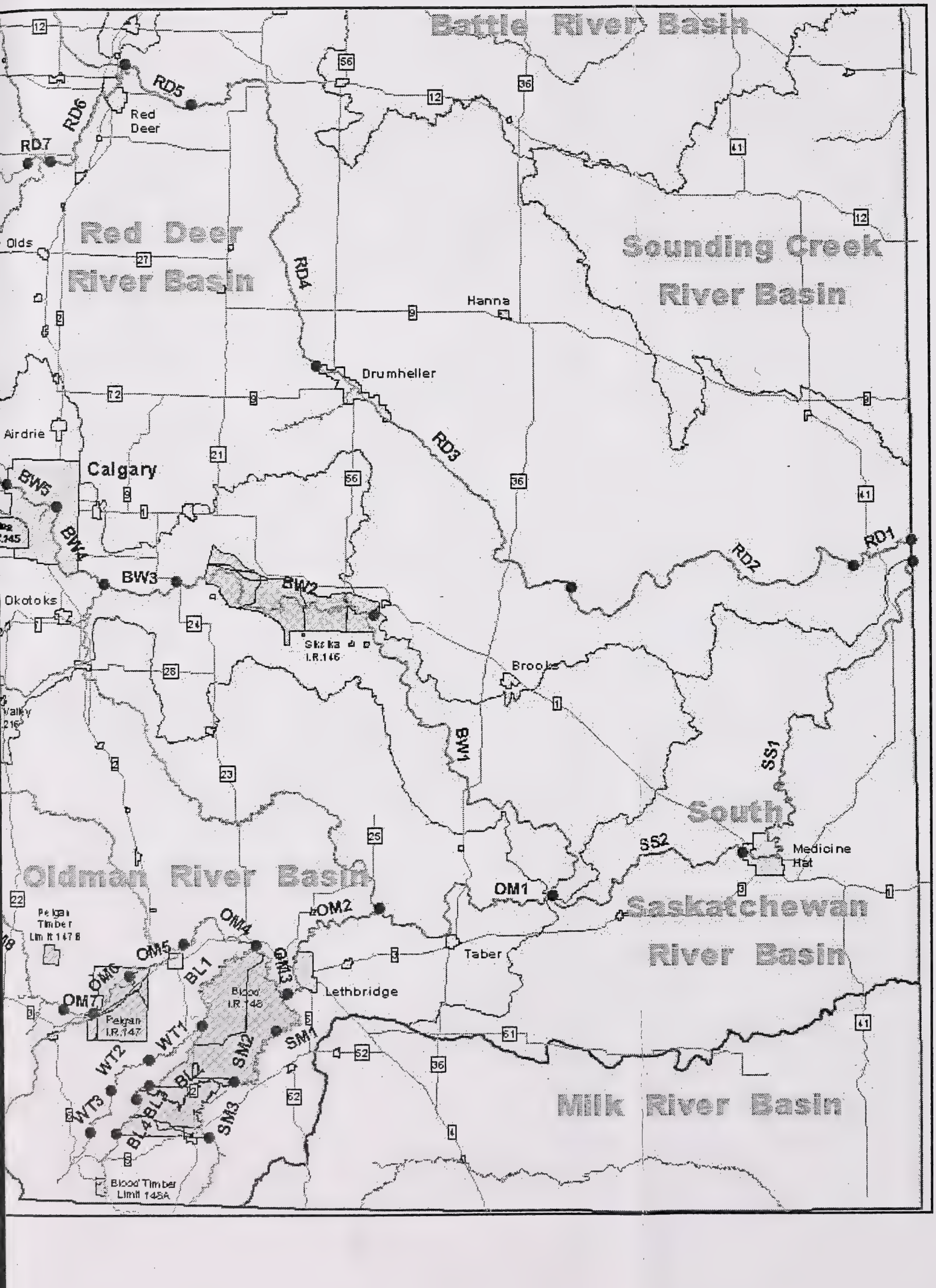
undaries for the SORAC Assessment in Southern Alberta



Managers who attempt to regulate a river system based on the premise of sustainable development must consider the three major functions (from Bond *et al.* (1992) and their discussions of aquatic ecosystems and wetlands) of the river in their planning strategy:

- life support – the ability of the river to be sustainable, to maintain its ecological integrity;
- social/cultural functions – aesthetics, recreation, education, etc.; and,
- commercial production – irrigation, industry, energy, etc. (see Appendix III, Figure III-1).

The SORAC report presents the results of a BJP qualitative assessment focusing on only the first of these three functions, the current ecological status of each sub-basin on a reach basis. This assessment will permit the subsequent prioritization of future quantitative research and analysis. The opinions expressed in this report will also provide guidance on the river's life support function for management planning.

3. ECOLOGICAL STATUS ASSESSMENT METHODS

3.1 Review of Methods

Most methods currently used for the assessment of river systems are based on analysis of long-term monitoring or targeted research data. Weakness in these data often leads to uncertainty in the results of assessments. The method adopted for SORAC is a hybrid of many common themes taken from some of the most widely used techniques including:

- U.S. Geological Survey's 'Ecological Status of the Upper Mississippi River' (USGS 1999);
- Ecosystem Diagnosis and Treatment (EDT) watershed analysis (MBI 2001);
- Range of Variability Approach (RVA) (Richter *et al.* 1997);
- Sustainable Rivers Audit (Cullen *et al.* 2000); and,
- Wetland Evaluation Guide (Bond *et al.* 1992).

The first two methods require large scale, long-term data sets and relatively complex analytical techniques, something that could delay the application of guiding policies by many years. The RVA and Sustainable Rivers Audit are more holistic-type approaches based on science and hypothesis testing through adaptive management, while the Wetland Evaluation Guide is a ranking system utilizing expert opinion only. The data and technology for utilization of the latter three methods are currently available for the SSRB and can be incorporated in future assessments. A brief overview of several major methodologies is summarized in Appendix I.

Insufficient time and resources were available to conduct the present assessment based on a comprehensive data analysis; therefore, the option selected was to derive a coarse filter type of assessment. This approach was based on key themes and indicators of widely accepted techniques that were used to elicit opinions from those people most familiar with the SSRB.

There is a general trend for resource managers to focus more on the holistic approach to ecosystem management and less on the management of individual species. A framework was designed to demonstrate the inter-related network of environmental themes that must be considered for an ecosystem management planning process (Appendix III, Figure III-1). These

themes or objectives have been identified as important in various methodologies and by AENV (undated(c)).

3.2 SORAC Assessment Methodology

A Likert scale (Neuman 1994) was used to evaluate the opinions of the participants of the three SORAC technical workshops via a series of questionnaires (Appendix III) on each reach of the river systems. The Likert scale is a widely accepted method of evaluating opinions using a survey approach that forces respondents to choose between a series of alternatives.

The SORAC assessment design was based on a similar study conducted by the US Geological Survey (1999) on the upper Mississippi River. A 4-condition status gauge, as defined by the USGS (1999), was used to rank the degree of impact or degradation for each river reach. The grading system, numerically scored 0 to -3, indicates whether the panel considered conditions in the reach to be:

- *Unchanged/Recovered* (0) – most factors have either remained relatively unchanged over time or recovered from any disturbance;
- *Moderately Impacted* (-1) – most factors have changed measurably over time and some are near or approaching ecologically unacceptable values;
- *Heavily Impacted* (-2) – many factors have degraded over time and are below or forecasted to be below ecologically acceptable values; and,
- *Degraded* (-3) – most factors are now below ecologically acceptable values.

These four grades coupled with a trend (improving, stable, or declining) provide an indication of the ecological status of the reach relative to an individual question. Each question represents a low-level objective which is an individual target or goal that a management plan could be aiming to protect (*e.g.*, a native species such as bull trout or a group of species that serve as indicators that the ecosystem has not been seriously altered). See Appendix III for the questionnaire and ecosystem assessment framework.

Two additional choices were available to the participants. These non-response grades were:

- *Not applicable* – some questions may not apply to all reaches; and,
- *Don't Know* – require more information (provides a flag of a possible data gap or indicates the question was outside the individual's area of expertise).

The last two choices were included to give respondents the flexibility to not grade a given reach. For example, an answer of 'not applicable' would be necessary if the question asked for an opinion on the riparian health of a reach located in a canyon without a riparian zone. Similarly, the respondents were given the alternative of selecting 'don't know' or require more information if they felt that their level of knowledge was inadequate to provide a grading for the reach.

For each question, the respondents were also asked if they thought the recent trend of the past 5 to 10 years would be:

- Declining;
- Stable; or,
- Improving.

While the categorical grade choices probed for information on the current status of the reaches, the additional trend-based question probed for insight into the likely future status of the reaches.

Respondents were also asked the following yes or no question for each reach: "Is this change [from the natural condition] due to water resource developments?" The 'cause-of-change' question probed primarily for changes due to water management implementation strategies. The importance of the final question was to distinguish hydrologic changes from other variables such as climatic changes, natural population fluctuations, watershed use changes, etc.

Finally, respondents were encouraged to augment their responses by answering open-ended questions related to several of the themes as well as providing comments on any responses they thought required more clarity.

3.3 Questionnaire Evaluation

The overall framework assumes that natural events in association with land and water use within the ecosystem (watershed) have an effect on the low-level objectives (Appendix III, Figure III-1). Changes in the target values for these low-level objectives affect how populations survive and function; these changes in community effect management decisions that are based on the high-level objectives, such as the maintenance of biodiversity or hydrologic characteristics (Appendix III, Figure III-1). The five high-level objectives correspond with the four elements identified by AENV (undated(c)) in their 'Strategy for the Protection of the Aquatic Environment'; their fourth element (the combination of species in riverine and riparian areas) was split into its two components for this framework.

The flow chart was used to demonstrate the ecosystem assessment framework (Appendix III, Figure III-1) that identified the major supporting linkages of the functions that are considered in a management plan. In order to standardize the terminology used in this report, the identifying labels selected from other assessment methodologies were functions, components, and objectives. The detail increases as one reads across the hierarchical ecosystem network from the 'function' of maintenance of ecological integrity through the biotic and abiotic 'components' to high-level 'objectives' and finally down to low-level 'objectives'. The low-level objectives are the level of detail at which questions were asked in order to reduce the breadth of a topic and try to minimize the range of possible (mis)interpretations. The high-level objectives are the scale at which quantitative programs would be designed to provide input to the life support function of the river (*e.g.*, RVA models could provide input for hydrologic alteration assessment).

In order to provide a means of evaluating the accuracy of the assessment, it was initially proposed to derive a two-tiered weighting system to apply to the responses of the participants of the Technical Workshops. In the first phase, each participant was asked to identify the relative importance of each question/objective. A numerical rating of 1 to 3 (representing less important, important, and more important) was applied with approximately ⅓ of the questions/objectives to fall into each weighting class (see Appendix III). The second weighting system was to be based on the consistency of the responses (variance of the numeric value of the responses) to provide less weight to responses to questions having a wide range of answers. Unfortunately, the high rate of 'no-response' replies caused the weighting schemes to provide results not consistent with

what was believed to be the respondent's intention. However, the importance rating of the questions is of interest for the relative positioning of the major themes in the assessment (Appendix III, Figure III-2).

The low response rate for many questions made the planned confidence rating difficult and meaningless without associating individual names and experience to the responses. The responses that were gathered from the workshops were combined into a single categorical value by taking the median response to each question by reach (see Appendix VI). These median responses for each question with at least one response were then combined to provide the median workshop assessment for that reach. These data, in addition to key identified issues from the workshops, were presented to the BJP for review in order to develop a consensus assessment.

3.4 Sub-basin Technical Workshops

Prior to the meeting of the BJP, Sub-basin Technical Workshops (workshops) were held in Lethbridge, Red Deer and Calgary. The purpose of the workshops was to obtain opinions from managers, scientists and operational staff working within each river basin. The participants were selected by AENV and, at each workshop, they were given an overview of the objectives of the ecological assessment, watershed maps (Appendix IV), a basin-wide map, reach descriptions and the questionnaire (Appendix III). The questions were read aloud and the participants had an opportunity to discuss the questions in relation to each reach as well as the entire sub-basin that they were evaluating. During each workshop, the main discussion points were recorded using a flip chart and notes were taken by local rapporteurs. Additionally, questionnaires were delivered to those individuals unable to attend the workshops but still interested in participating in the assessment process.

The opinions obtained from the three sub-basin workshops provided the basis of the presentation to the BJP. The opinions also gave the panel insight into how participants of the regional workshops graded the river basins.

3.5 Expert Panel Meeting

The BJP meeting was held in Calgary two weeks after the sub-basin workshops. The participants from the sub-basin workshops were invited to attend along with independent experts and several experts from Golder. The BJP was presented with the opinions from the workshops in the form of sub-basin summary charts, and for each reach a gauge rating system along with a list of the main issues identified. The BJP was provided watershed maps of each of the sub-basins, a map of the entire basin, and descriptions of each reach. They were also given the opportunity to comment on each of the reaches, and the discussion was recorded using a flip chart. A rapporteur also took notes.

The BJP reviewed the workshop findings and major concerns and then accepted or modified the final assessment. It is important to note that a reach with both high and low ranks for its low-level objectives will tend to result in an assessment that suggests a status near the middle of the range. Therefore, the reach summary in Appendix VII and the question by question (theme) summary of Appendix VI are both necessary to fully interpret the results.

3.6 SORAC Participants

The participants for the regional workshops were selected by AENV, and included representatives from AENV, Alberta Sustainable Resource Development (ASRD), Alberta Agriculture, Food and Rural Development (AAFRD), University of Lethbridge, and the Cows and Fish Program. The participant lists for the workshops and the BJP meeting are presented in Appendix V.

Prior to the assessment, participants filled out a short questionnaire outlining their professional backgrounds. The majority of participants reported work experience with ASRD and AENV. Others reported having related experiences with Parks Canada, within consulting firms and in different capacities internationally. Some participants attended as observers; these individuals took part in the meetings to learn about the assessment process and the respective river system in order to provide them with background information for water management planning and other initiatives. The majority of participants reported having expertise in fisheries with the remainder of the participants having expertise in community ecology, water quality, and hydrology.

3.7 Atlas and Supporting Data

Maps of the sub-basins (Appendix IV) were prepared for use at the Technical Workshops and the meeting of the BJP. These maps of each sub-basin, by reach, were based in part on data sets prepared for AENV as part of earlier work on the Instream Flow Needs (IFN) classification assessment (Golder 2001). These data are presented on a background of band 5 Landsat imagery made available for this purpose by ASRD (Resource Data Branch). The watershed boundaries were developed from a GIS flow model (ArcInfo: Watershed) using a flow direction grid (cell size 100 m) created from a digital elevation model (DEM). The final outer boundaries are slightly different from those currently in use for the 'unofficial' provincial database for the coverage of watersheds; these latter boundaries were created by digitizing from photography and hard copy maps, and not from DEMs.

The watershed boundaries include all the land draining into a reach. For the maps prepared for this assessment, when the reach boundary occurs at the confluence of a tributary, the watershed area for the incoming tributary is a part of the watershed for the lower reach. To derive a conservative estimate of modelled flow in a reach, AENV assumes all withdrawals are taken from the upstream end of the reach while all additions are added to the downstream end of the reach.

AENV (Tom Tang 2002, Hydrology Modelling Group, AENV, Calgary, Alberta, pers. comm.) has made available a series of hydrographs showing mean actual (recorded) flow and mean 'naturalized' flow (*i.e.*, modelled flow that would have occurred without any regulation or withdrawals) for the total available time periods (Appendix VII). It should be noted that hydrograph data for the recorded flows are often incomplete, with no data for some seasons or years. In many reaches, the naturalized flows are actually modelled flows of what water would have moved past that point had no diversions or control devices been in existence; thus, in many situations complete naturalized data sets can be generated from incomplete records of actual flows. It is therefore important to note the time periods for the available data for each hydrograph shown in Appendix VII.

3.8 Sub-basin Summary and Detailed Reach Data Based on BJP Opinions

The responses by reach for each question were combined by taking the median value of the numeric response (0 to -3) from all sub-basin technical workshop participants that provided a grade that was based on the four status categories. A summary of the combined responses can be found in Appendix VI. After combining data in this manner, three reach/question combinations had no response; these were all for the Bow River. There were more none-response answers to the questions posed to the participants in the sub-basin technical workshops than had been expected. This was most prevalent in the riparian and biodiversity themes, fields that many of the experts felt their limited experience hampered their ability to make a knowledgeable response. From the summary response tables, the median reach value of the median question responses for each reach was calculated. The participants also assessed the 5- to 10-year trend; these are indicated in the grade charts of the reach summaries by a pointer beside the assigned grade. The direction of the pointer (up, down, or sideways) indicates the trend (improving, declining, or stable).

These results and the major issues of concern identified at the sub-basin technical workshops were presented to the SSRB expert panel. The BJP reviewed these and other information from their personal experience to make the final assessment of the ecological condition of each reach. Within each sub-basin there was an attempt to ensure internal relative consistency of the reach ratings. Inter-relating the sub-basins was not possible as the technical workshops met on separate occasions with different participants and members of the BJP generally did not have equal experience in all sub-basins.

Summaries of the ecological status assessment for each sub-basin can be found in Section 5. The reach assessments and the major issues raised by the workshop participants and the BJP are detailed in Appendix VII. A list of the knowledge gaps that were identified by the participants as hindering their ability to make confident responses for that sub-basin is also presented in Appendix VII.

4. STATUS OF ECOLOGICAL CONDITION

4.1 Geomorphology of the Major Rivers (Tributaries) of the SSRB

A detailed description of the rivers and major tributaries of the SSRB is available in a report on the environmental requirements of fish populations prepared by the Fish and Wildlife Branch of the Alberta Department of Energy and Natural Resources (Longmore and Stenton 1981). Some limited extracts from that document have been presented in this report to provide background. A series of internal drainages between the Milk River and the South Saskatchewan River were included in Longmore and Stenton (1981) and the 1996 Alberta State of the Environment Report (AENV undated(c)). However, these internal drainages have been left out of the more recent provincial GIS data sets including the GIS data used for this report and the identified planning area for the SSRB Water Management Plan.

4.2 Red Deer River Sub-basin: Overview

The Red Deer River in the study area is composed of eight reaches (Appendix IV, Table IV-1), seven of which were previously identified by staff of ASRD and AENV. The eighth reach was identified by Golder, at the request of AENV, as a single reach upstream of the other seven. It was to act as a reference reach, although it was understood that no reach could be identified as natural enough to be considered an untouched control. The entire river above this reference reach (above the Water Survey of Canada (WSC) gauge in Sundre) was referred to as the headwaters.

The Red Deer River has its source about 30 km inside the eastern boundary of Banff National Park in the Rocky Mountains, from where it flows for about 708 km to the Alberta-Saskatchewan border (Appendix IV, Figure IV-1). The river then flows for about 18 km from the border to the confluence with the South Saskatchewan River in Saskatchewan. The area of the watershed, about 46,998 km^2, is the largest of the three sub-basins of the SSRB in Alberta. It comprises over 42% of the total area of the SSRB. Although large, the Red Deer River has the least number of large impoundments (one), and the lowest percentage of water extraction (from the mainstem of the river) of all the major SSRB sub-basins.

The Red Deer River upstream from Sundre is a fast-flowing, clear, cold mountain stream. Near Sundre the channel becomes braided, and there are numerous bars and islands. The streambed consists of cobble and bedrock with some silt deposition in the backwaters. The braided channel is susceptible to shifting during periods of high discharge, and that has resulted in some pipeline crossings becoming exposed in this section of the river.

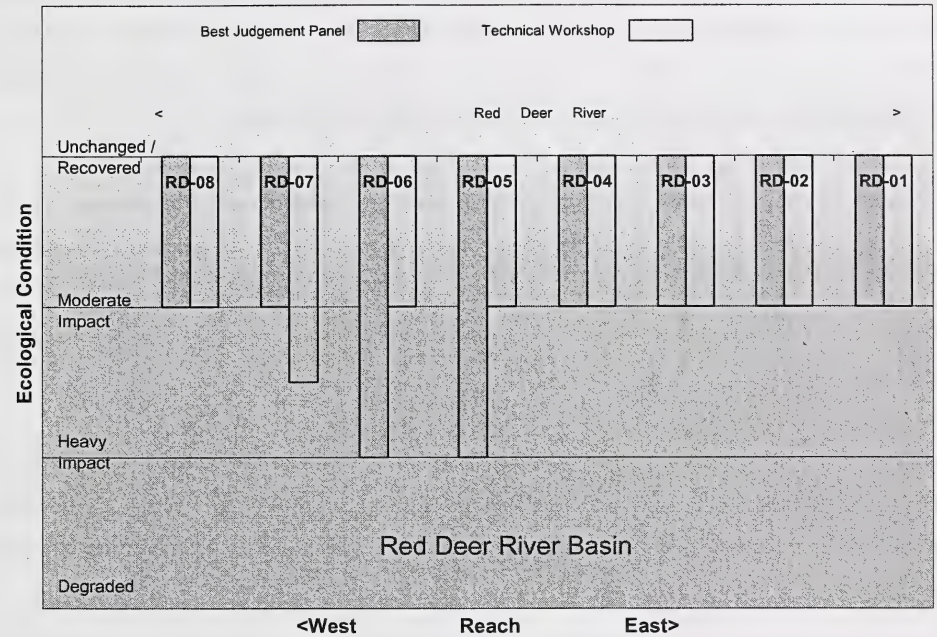
The BJP thought the reaches of the Red Deer River were in generally better condition than those of the Bow or the Oldman rivers. The reasons given were the relatively natural flow and the relatively low quantity of chemical and organic contaminants input to the system.

Gleniffer Lake, which was created by the Dickson Dam (located at the upstream end of reach RD-07) is the only major impoundment on the mainstem of the Red Deer River. The BJP judged the reach above Gleniffer Lake (RD-08) the least impacted reach of the Red Deer River based on its lack of development, the relatively natural state of the mostly forested watershed and the natural flow regime (Figure 2) (see Appendix VII). Numerically, because of the categorical type values, the four lower reaches and RD-07 were all scored the same as RD-08 by the BJP (Figure 2).

The middle reaches (RD-05 and RD-06), which are below the City of Red Deer and receive inflows from the Medicine and Blindman rivers, were judged by the BJP to be in the worst ecological condition among the reaches of the Red Deer River sub-basin.

All reaches except RD-08 were considered to have a declining 5- to 10-year trend. RD-08 was considered stable. The effluent from municipal treatment facilities was considered a major factor in this declining trend, particularly as it relates to water quality.

Figure 2
Ecological Condition, by Reach, of the Red Deer River. The Final Assessment of the 'Best Judgment Panel' Convened in Calgary (Solid Bars) Utilized Information Provided by the Technical workshop Held in Red Deer (Open Bars).



Note: The assessment ratings are relative within the individual sub-basin. The degree of cross-calibration between sub-basins by the 'Best Judgment Panel' was limited.

4.3 Bow River Sub-basin and South Saskatchewan River Sub-basin[1]: Overview

The Bow River in the study area is composed of five reaches, four of which have been described by staff of ASRD and AENV (Appendix IV, Table IV-2). The fifth reach was defined by Golder, at the request of AENV, as a single reach upstream of the other four. It was to act as a reference reach, although it was understood no reach could be identified as natural enough to be considered a control. The entire river above this reference reach (above Bearspaw Dam) was referred to as the headwaters. These headwaters include several reaches that were not included in this ecological condition assessment.

[1] The South Saskatchewan River sub-basin includes the two reaches of the South Saskatchewan River below the confluence of the Bow and Oldman rivers.

The Bow River flows for about 625 km from the Rocky Mountains to the confluence with the Oldman River, referred to as Grand Forks (Appendix IV, Figure IV-2). The length of the Bow River outside the eastern boundary of Banff National Park is 498 km. The area of the watershed, about 25,165 km^2, is the second largest of the three sub-basins of the SSRB in Alberta. The two reaches of the South Saskatchewan River within Alberta are 286 km in length and have a watershed area of about 12,148 km^2. The Bow River and South Saskatchewan River sub-basins comprise nearly 23% and 11% of the total area of the SSRB, respectively.

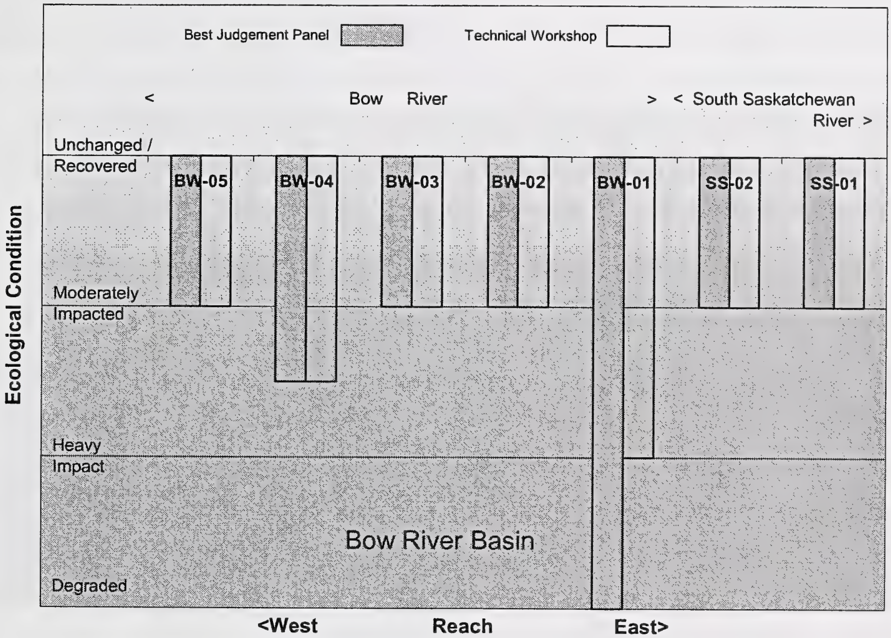
Of the four sub-basins, the Bow River has the greatest number of major impoundments and the highest percentage of water extraction during the summer months. The Western Irrigation District (WID) Weir (above reach BW-04) in central Calgary, the Carseland Weir (above reach BW-02), and the Bassano Dam (above reach BW-01) are the major extraction points on the mainstem of the Bow River (see Appendix VII).

Generally, the BJP respondents thought the reaches of the South Saskatchewan River were in better condition than the lower reaches of either the Bow or the Oldman rivers. The reasons given were the increased flow and the ability of one of the sub-basins to provide water when the other might be in a low discharge period.

The lowest reach on the Bow River (BW-01) is warm (in summer), eutrophic, and shallow with a significantly reduced flow due to upstream water extractions and, because of these attributes, was judged by the BJP to be in the worst ecological condition of all river reaches in the SSRB (Figure 3). Reach BW-03 was judged by the panel to be enhanced by the re-regulated flows from Bearspaw Dam and flows from the Highwood River (175 km in length). Flows in BW-03 and downstream reaches are enhanced during winter months due to releases from upstream hydroelectric plants. This enhanced flow coupled with the nutrient load from the City of Calgary is thought to have resulted in a productive sport fishery in this region of the Bow River.

All the reaches were considered to be in a stable 5- to 10-year trend except for BW-01, which is considered to be declining even though it is considered degraded at the present time. A general concern was expressed related to habitat connectivity and the effect of dams and diversions on fish movement. On the positive side, water quality was seen as improving as a result of upgraded municipal treatment facilities.

Figure 3
Ecological Condition, by Reach, of the Bow and South Saskatchewan Rivers. The Final Assessment of the 'Best Judgment Panel' Convened in Calgary (Solid Bars) Utilized Information Provided by the Technical Workshop Held in Calgary (Open Bars).



Note: The assessment ratings are relative within the individual sub-basin. The degree of cross-calibration between sub-basins by the 'Best Judgment Panel' was limited.

4.4 Oldman River Sub-basin: Overview

The Oldman River in the study area is composed of eight reaches, seven of which were identified by staff of ASRD and AENV (Appendix IV, Table IV-3). The eighth reach was identified by Golder staff, at the request of AENV, as a single reach upstream of the other seven. It was to act as a reference reach, although it was understood that it could not be identified as natural enough to be considered a control. The entire river above this reference reach (above Waldron's Corner) was referred to as the headwaters. These headwaters would include several reaches if similar criteria were used to identify separate reaches in these upper waters.

Flowing for 450 km from the Rocky Mountains eastward to the arid prairie, the Oldman River system has a total drainage area of about 26,357 km^2, nearly 24% of the total area of the SSRB

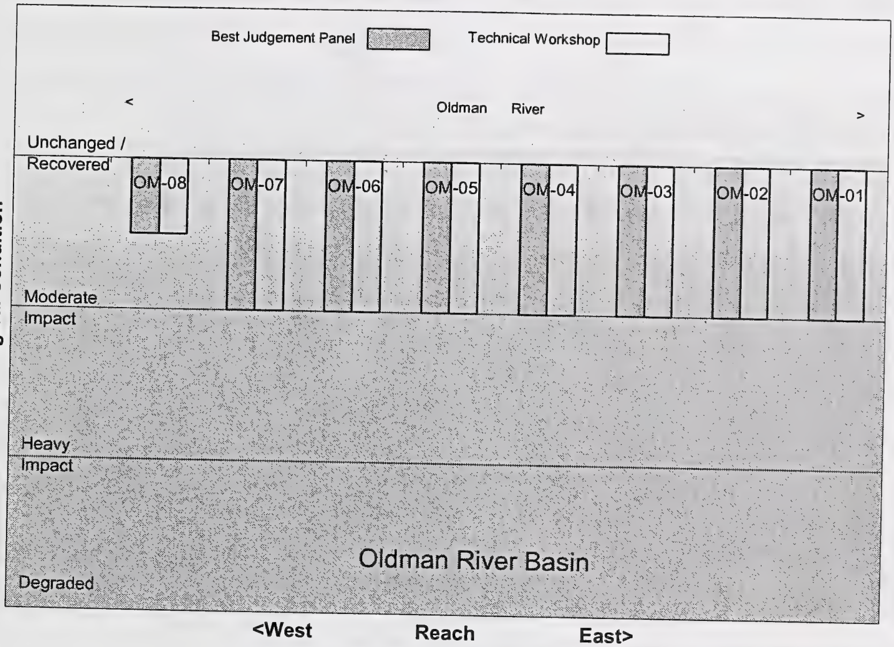
(Appendix IV, Figure IV-3). The Oldman River drainage includes the southern tributaries with a drainage of about 5,676 km^2, these three smaller rivers are often treated as a separate entity. Upstream of the Oldman Dam, the initial 100 km of the Oldman system consists of cold, fast-flowing mountain streams. From its source (a small alpine lake on Mount Lyall) to ‘the Gap’ through the Livingston Mountains, the Oldman River flows through a steep valley. As the river leaves the Rocky Mountains, it flows through cultivated and range land along the southern edge of the Porcupine Hills. Between the Oldman Dam and Lethbridge, the Oldman River flows for 190 km through intensively cultivated plains. The streambed, which is predominantly gravels, is exposed on bars and islands. Between Lethbridge and the ‘Grand Forks’, the warm, turbid Oldman River winds slowly east for 158 km across the flat, arid prairie to its confluence with the Bow River to form the South Saskatchewan River.

Of the three major SSRB sub-basins, the Oldman River is in the driest region of Alberta and has the smallest watershed, even if including the southern tributaries (the St. Mary, Belly and Waterton rivers), which have historically been treated as a separate entity. These three tributaries lie between the Milk River (part of the Mississippi drainage) in the south and the Oldman River in the north. The largest impoundment in the sub-basin is the Oldman Dam, which was completed in 1991. The Lethbridge Northern Irrigation District (LNID) weir above Fort Macleod is the point of major water extraction from the Oldman River.

Although there was much concern expressed about the ecological integrity of the Oldman River sub-basin, the BJP rated it as only moderately impacted below the Oldman River Reservoir (Figure 4). The main concerns related to the major dam and diversion and their impact on fish habitat connectivity, and the effects of reduced flooding on riparian diversity.

The 5- to 10-year trends were considered stable for all Oldman River reaches and there was a general feeling the water quality was improving or had improved due to the upgrading of the Lethbridge sewage treatment facilities and the enhanced flows during low flow periods.

Figure 4
Ecological Condition, by Reach, of the Oldman River. The Final Assessment of the 'Best Judgment Panel' Convened in Calgary (Solid Bars) Utilized Information Provided by the Technical Workshop Held in Lethbridge (Open Bars).



Note: The assessment ratings are relative within the individual sub-basin. The degree of cross-calibration between sub-basins by the 'Best Judgment Panel' was limited.

4.5 The Southern Tributaries of the Oldman River Sub-basin: Overview

The Oldman River sub-basin includes the St. Mary, Belly and Waterton rivers as major tributaries from the south and southwest. These three southern tributaries lie between the Milk River (part of the Mississippi drainage) in the south and the Oldman River in the north. They have historically been managed as a separate entity comprising about 22% (5,676 km^2) of the Oldman River drainage.

Together, the three southern tributaries include 10 reaches, 7 of which have been previously identified by ASRD and AENV staff (Appendix IV, Table IV-4). The upper reach on each river was identified by Golder, at the request of AENV, as a single reference reach upstream of the previously identified reaches, although it was understood that they could not be identified as

natural enough to be considered controls. The entire river above each reference reach was referred to as the headwaters.

As stated previously, the Oldman River sub-basin is in the driest region of Alberta. The watersheds of the lower reaches of the southern tributaries are also very dry and have a long history of water extractions for irrigation. The largest impoundments in these watersheds are the St. Mary and Waterton reservoirs (Appendix IV, Figure IV-4).

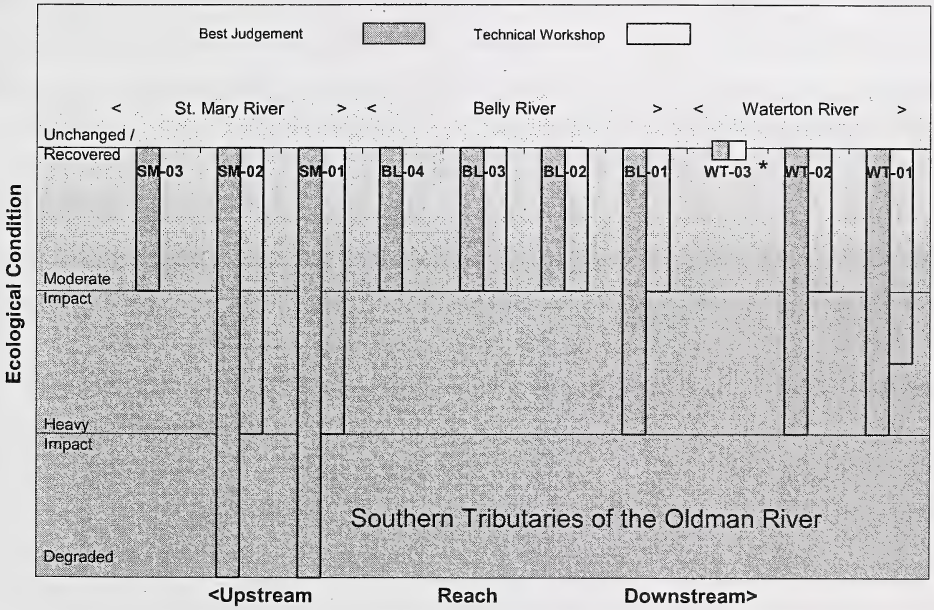
The St. Mary River, flows approximately 163 km from the International Border to the Oldman River;, it is a clear, cold river flowing through the foothills to the St. Mary Reservoir. Downstream of the reservoir, as it flows to the prairie, the river becomes broader and warmer, with occasional islands and bars. Despite the nearly 1500 km^2 of watershed, the St. Mary River provides little water to the Oldman River due to the low precipitation and high rate of extraction that occurs both in Canada and the United States.

The Belly River flows for approximately 172 km from the International Border through foothills and prairie to the confluence with the Oldman River. Over this distance, the geomorphology and ecology of the river change dramatically. The Belly River changes from a swift, turbulent river in the foothills to a broad, winding river crossing the flat, arid prairie.

The Waterton River flows for one third of its length through the United States. The 96 km within Alberta flows from Montana's Rocky Mountains through the foothills and prairie of Alberta to its confluence with the Belly River. Open rangeland borders the Waterton River in the foothills; irrigated, cultivated fields surround the Waterton Reservoir and the river below it.

Among the reaches of the southern tributaries, the lower two reaches of the St. Mary River (SM-01 and SM-02) are considered degraded (Figure 5). These two reaches and the lowest reach of the Bow River were the only reaches in the SSRB that were given a degraded classification. At the other end of the spectrum, the upper (reference) reach of the Waterton River (WT-03) was considered Unchanged/Recovered, and the only reach within the SSRB study area to achieve this ranking. The lower two reaches of the Waterton River, and the lowest reach of the Belly River were all considered heavily impacted (Figure 5).

Figure 5
Ecological Condition, by Reach, of the Southern Tributaries of the Oldman River.
The Final Assessment of the 'Best Judgment Panel' Convened in Calgary (Solid Bars)
Utilized Information Provided by the Technical Workshop Held in Lethbridge (Open Bars).



Note: The assessment ratings are relative within the individual sub-basin. The degree of cross-calibration between sub-basins by the 'Best Judgment Panel' was limited.

* **WT – 03** was ranked as unchanged / recovered by both the BJP and the Technical Workshop.

The lower two reaches of both the St. Mary and Belly rivers were considered to be in a declining trend, while the remaining reaches of these rivers were evaluated as stable. The Waterton River was assessed to be stable except for WT-02, which was considered to be in a state of decline.

5. IMPROVING THE ECOLOGICAL ASSESSMENT APPROACH

5.1 Options for Improvement

The proposed hierarchical ecosystem assessment framework has five major themes or high-level objectives (hydrology, limnology, habitat connectivity, sustainability/resilience and biodiversity). The key aspects of each theme were included in the questions posed to workshop participants in order to develop the qualitative assessment. The intent of the assessment was to use it as a starting point for building a more comprehensive and defensible assessment approach. It is desirable that future modifications to the assessment approach include quantitative data analysis, in order to provide a more defensible assessment that relies more on data and less on qualitative opinion.

The general types of modifications that could be made to the ecological condition assessment framework include the following:

1. Adjusting the scope of the assessment by altering the number of high-level objectives (themes) and/or the type of information represented by those themes.
2. Adjusting the scope of the assessment by altering the number of questions and/or the type of information addressed by the questions related to each theme.
3. Using quantitative data analysis, either in addition to or instead of qualitative opinion, to provide answers to the questions.
4. Restructuring some of the questions in a way that facilitates the ability to address the questions with quantitative data analysis.
5. Altering the number of ecological status categories and the narrative descriptions of those categories; with a more data-based assessment, it may be possible to identify ecological status with a greater degree of precision and reliability.

All of these types of modifications could be made in a manner that retains compatibility with the assessments provided in this report while working towards a more comprehensive, defensible, and data-based assessment approach.

The key to developing an improved assessment approach will be incorporating relevant quantitative data, and analyses of those data, to provide the basis for a more rigorous evaluation of ecological status. For some types of information (*e.g.*, hydrology) extensive data sets are already available. For other types of information (*e.g.*, benthic invertebrates, fish populations, and riparian communities), long-term monitoring programs will be required to collect quantitative data.

Of the five major themes, hydrology and limnology have the most complete available data sets and the longest running monitoring programs. The hydrologic data are sufficient to begin using the RVA method of quantitatively assessing hydrologic alteration within the SSRB rivers (Richter *et al.* 1996). If desired, these analyses can also be used to develop initial flow targets based on hydrological statistics. These targets can be refined by using an expert panel to identify hydrologic events that are key in the SSRB for maintaining the aquatic and riparian ecosystems and by an adaptive management approach supported by appropriate monitoring programs. The results of previous IFN studies in the SSRB, as well as similar studies that may be undertaken in the future, can also be used to quantitatively evaluate some of the effects of existing or proposed flow regimes on aquatic habitats. Some modifications to the current hydrology and water quality monitoring programs in the SSRB may be needed to provide a robust data set that would fill the knowledge gaps identified by the BJP.

It is most difficult to develop quantitative assessment procedures for the biological themes. Some components (*e.g.*, fish populations) are subject to a wide range of natural variation, and interpretation of the monitoring data make identification of trends difficult, even with the best of data. Long-term monitoring is necessary to ensure that, for an extended time, appropriate and consistently collected data will be available to support the ecological assessment approach. It is necessary before the monitoring starts to define the monitoring criteria, how they are to be assessed and what conditions may trigger some management action (Boon 2000). The highly variable biological community requires indicators other than single species, as well as metrics and analyses that are relevant to the questions being addressed. Walker *et al.* (2002) addressed the need for adaptive management to sustainably manage any social-ecological system. Many uses of indices of biological integrity (IBI) have failed through a lack of adequate testing of the measured metrics (Karr 1999). It is thus necessary to ensure a consensus among the various partners before any long-term commitments are made to the necessary monitoring efforts.

A key monitoring program that would be useful in order to assess the biological themes is long-term monitoring of benthic invertebrates. The benthic community is a particularly useful indicator because it is resident in the habitats occupied and responsive to physical and chemical changes over a relatively short term. At present, fish and aquatic plant surveys comprise the major biological monitoring effort within the SSRB. Although important, fish are subject to a wide range of population variability (for various reasons) that makes it difficult to assess short-term changes and/or gradual trends. However, monitoring of spawning effort, through redd surveys, may provide alternate data to develop status reports that could be used for both the monitoring of biological integrity and the assessment of the status of fish stocks.

5.2 Recommendations for Improvement

Further development and improvement of the ecological condition assessment approach will need to be carefully planned. In order to provide a more comprehensive and defensible assessment approach, it will be necessary to incorporate various quantitative analyses that will have to be supported by monitoring programs to collect the appropriate data. Both the data collection and analysis phases can be quite costly and time consuming. It is therefore important to undertake further development of the assessment method with careful consideration of the feasibility and long-term commitment to any proposed enhancements to the approach.

It is recommended that, prior to implementation of any changes to the assessment approach, an expert panel (or panels) be convened to undertake the following activities:

- select indicators to represent and integrate the many aspects that comprise each environmental attribute; these indicators would be selected to provide reportable measures of the status of the river ecosystem;
- determine what data are to be collected, what spatial and temporal scales the data should cover, and how the data are to be managed, analyzed, and reported; and,
- determine critical levels for each indicator and identify what specific management options may be available and desirable if those levels are exceeded.

Once the panel(s) have made these decisions, then annual audits or status reporting, modelled on State of the Environment reporting, could begin. Five-year comprehensive audit reports could

then be used as input to large scale river management plans. Cullen *et al.* (2000) provide an example of how such a 'Sustainable Rivers Audit' could be designed. Such a program would allow a comprehensive cooperative monitoring plan to provide the long-term data required for the analysis necessary to further develop the SORAC assessment from a provisional coarse filter qualitative approach toward a more defensible quantitative assessment. It will be necessary to build political commitment based on an understanding of the requirement for long-term monitoring that will provide the quantitative input for a sustainable river management plan. Without such a political will any such monitoring program(s) will be highly vulnerable to failure.

6. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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APPENDIX I

ANNOTATED LISTING OF THE METHODS REVIEWED

ANNOTATED LISTING OF THE METHODS REVIEWED

A review of ecosystem evaluation methods used to assess ecological condition of rivers and wetland systems was carried out. This was done in order to find an existing, or assist in the development of a new, approach that would provide a credible qualitative assessment that could be conducted with the resources currently available.

The following information provides a summary of key ecological assessment approaches identified during the review of materials identified by the SSRB team. Based on this information:

- there are few holistic ecological status assessment approaches available and none that do not use hard data;
- much literature is available to provide input on methodology or techniques that should be employed within an ecosystem assessment (*e.g.*, Richter *et al.* (1997) RVA approach, or Norris and Thoms (1999) discussion of what constitutes river health); and,
- the main holistic approaches that should be considered in any prospective evaluation of methods include:
  - The USGS (1999) ecological status assessment of the Mississippi River, which provides much information on indicator development, monitoring and provides a system of criteria/gauges to assess ecosystem health. This is a long-term, data intensive monitoring and research program that results in a largely qualitative assessment approach.
  - CRC for Freshwater Ecology (Cullen *et al.* 2000) describes the Scope of the Sustainable Rivers Audit which provides a framework for assessment, indicator development, techniques and methods to assess overall ecological condition status. This is also based on cooperative, long-term data collection programs, modelling, etc.
  - The EDT Watershed Analyses (MBI 2001) provides a tool to evaluate ecological conditions based on the performance of salmonids through various life stages. The concepts of a working hypothesis of the ecosystem and use of environmental correlates used in this approach could be adapted to fit in with other ecosystem

assessment approaches. This analytical modelling technique does not provide a holistic evaluation of ecosystem components that are unrelated to fish.

- The Wetland Evaluation Guide (Bond *et al.* 1992) provides an approach to assess wetlands (sensitivity to development) using existing understanding of wetland function/structure within an ecosystem and a question survey. The system of questions and some of the criteria for wetland ecosystem evaluation could be adapted to river systems to provide a rapid tool for ecosystem evaluation (including a sensitivity/status ranking system).
- The Missouri Resource Assessment Partnership (MoRAP) (online reference: http:// www. cerc. usgs. gov/ morap/ default.asp) is an ongoing mapping program. Numerous projects feed into a central (GIS) database. This information can be used for various ecological assessment purposes (*e.g.*, delineation of ecological land types, etc.). Most assessment techniques will ultimately require similar spatial data inventory and evaluation.
- The Water Resource Plan (requirement for water use in Queensland, Australia) (*e.g.*, Pioneer Valley WRP online reference: http:// www. nrm. qld. gov. au/ wrp/ pioneer.html) provides an excellent framework for ecosystem condition assessment based on hydrological modelling and ecological risk assessment. In this case, the flow regime is recognized as the fundamental component of ecosystem structure. The use of key flow indicators and environmental performance measures (benchmarks) provide standard criteria to evaluate ecological conditions. Other water resource plans are also available from this source.

A few additional materials, which do not generally include holistic methods for assessing ecosystem status but contribute to development of evaluation methods, are also included in the following tables. Many additional articles have not been reviewed, as many of these are variations of those discussed above and in the following tables. However, as most of the techniques require data and model development, these additional sources should be examined further when the managing authority has determined how they plan to proceed. Other literature (*e.g.*, regarding the Building Block Methodology and the Australian River Assessment System (AUSRIVAS)) should also be reviewed when considering development of the local models and associated monitoring programs.

I Holistic River Ecosystem Evaluation

I.1 Ecological Status and Trends of the Upper Mississippi River System (USGS 1999)

Approach/ Method Type	River System Features	Data Type	Scale	Data Inputs	Framework or Indicator Development Process?	Ecosystem Indicators?	Ec Ev C
Compilation of scientific information and methodology to gauge ecological status (health) and trends.	North America -floodplain river, heavy navigation, highly developed, important economic and cultural concerns.	Qualitative from quantitative analysis.	Multi scale: basin, stream network, floodplain reach, navigation pools and habitats.	Long-term monitoring of physical and biological characteristics of river reaches, historical review, etc.	Individual indicators are not developed. However, ecological health assessment criteria are developed with discussion of unique features of floodplain river system.	Biotic (benthic invertebrates, mussels, fishes, birds), hydrologic variability, water and sediment quality, watershed relationships and floodplain processes (connectivity, flooding), geomorphologic, water quality, land use, human influence	Native recove and sustai also e and cu naviga recrea

I.2 Scope of the Sustainable Rivers Audit (CRC for Freshwater Ecology (Cullen *et al.* 2000))

Approach/ Method Type	River System Features	Data Type	Scale	Data Inputs	Framework or Indicator Development Process?	Ecosystem Indicators?	Ecosystem Evaluation Criteria?
Sustainable Rivers Audit (SRA) - a process for collecting and reporting on ecological condition/ health of land and water and factors affecting it.	Australia – Murray Darling Basin (extensive regulation, irrigation and water resources problems, *i.e.*, salinity).	Qualitative/ quantitative.	Reach sampling to determine river valley features/ ecological status.	Long-term monitoring of physical and biological characteristics of river reaches, historical review; modelling	Framework for assessment, planning audit, and indicator development process is included. Step-by-step plan provided.	Biological (primary = invertebrates, fish; secondary = algae, riparian vegetation, aquatic plants, wetlands and birds); hydrological (flow regime), water quality and habitat structure index (reflecting connectivity).	Numerous methods are used to evaluate biological and physical indicators; *e.g.*, pressure-biota-habitat (PBH), Index of Stream Condition (ISC), Index of Biotic Integrity (IBI). Specific sub-index developed for connectivity, riparian and aquatic vegetation, woody debris, geomorphic environment (stability) wetlands.

ystem uation eria?	Aggregated Measure of Ecosystem Status?	Forecasting?	Upgradeable/ Adaptive	Question-based evaluation criterion	Statistical Foundation?	Reporting Protocol?	Pros	Cons
pecies, ability ability; nomical ural (*e.g.*, on, on).	YES - gauge system: degraded, heavily impacted, moderately impacted, unchanged/ recovered as well indication of stable, improving or degrading status.	Yes - potential deterioration and improvement - speculation.	The criteria could be improved with metrics; criteria and gauge measure can be changed with improved information.	No	No	No	Qualitative; simple system of criteria and gauge measure of ecosystem health; seems holistic.	15 years of data and expert knowledge used to evaluate criteria - hard to replicate.

Aggregated Measure of Ecosystem Status?	Forecasting?	Upgradeable/ Adaptive	Question-based evaluation criterion	Statistical Foundation?	Reporting Protocol?	Pros	Cons
Comprehensive Sustainability Assessment (CSA) every 5 years. Possible use of red-amber-green system and the Victorian Index of Stream Condition. Agreed measure of river health not yet determined.	Not presently.	Adaptive approach inherent.	No	No	Yes – using aggregate measures at various valley sections to provide comparison. Annual and five year reporting.	Adaptive approach; integrating quantitative indexes (*e.g.*, IBI); emphasizes ecological outcomes of physical variables *e.g.*, flow (suggesting hydrology is not a surrogate, but driver of ecological processes); includes a plan to complete audit.	$1,000,000 cooperative project; extensive period of reviewing existing methods and development of protocols, indexes and health measures to complete comprehensive sustainability audit; major data requirement. Modelling.

I.3 The EDT Watershed Analysis (Draft) (MBI 2001)

Approach/ Method Type	River System Features	Data Type	Scale	Data Inputs	Framework or Indicator Development Process?	Ecosystem Indicators?	Ecosystem Evaluation Criteria
Ecosystem Diagnosis and Treatment (EDT) – a habitat-based procedure for relating environmental conditions to the performance (trajectory) of salmon (diagnostic species) populations.	Entiat River Watersheds, Washington, USA.	Qualitative/ quantitative.	Basin, sub-basin and stream reach scales.	Estimated habitat parameters, species life history perspectives – index of environmental correlates.	A characterization of the environment and resultant species performance constitutes a working hypothesis of the ecosystem which guides strategic assessment and any short- or long-term recover planning. A set of correlates provides indexed inputs to EDT model.	Basic input data (Location, dimensions, land use, land cover, environmental data) and a standard list of ecological attributes (hydrologic characteristics, stream corridor structure, water quality and biological community).	Analytical method to relate habitat feature and biological performance (productivity, capaci and life history diversity of salmon) support recovery planning – a 'scientific model' suc that a working hypothesis of the watershed provides metrics to gauge progress. Statistica models reduce complexity and establish linkages (correlations) to test the working hypothesis.

I.4 Wetland Evaluation Guide: Final Report of the Wetlands Are Not Wastelands Project (Bond *et al.* 1992)

Approach/ Method Type	River System Features	Data Type	Scale	Data Inputs	Framework or Indicator Development Process?	Ecosystem Indicators?	Ecosystem Evaluation Criteria?	
Three stage progressive approach for evaluation of wetlands to establish and compare value and assist in management decisions.	Wetlands.	Qualitative.	Wetland.	Long-term monitoring of physical and biological characteristics of river reaches, historical review; modelling	Progressive three step approach: 1) general review and evaluation of information, 2) detailed inventory of wetland functions and benefits, and 3) specialized analysis based on specific values/requirements.	In the wetland evaluation approach, a survey is used to establish values. These are based on understanding of wetland functions including its role in ecosystem health.	Criteria of wetland function and hydrological, biogeochemical, habitat, ecological, aesthetic, recreational, agricultural, natural resource, etc., values are used. Critical criteria are subject to rules which recognize wetland significance. Relative rating of the level of wetland/project values is also produced.	S li s a v e c

?	Aggregated Measure of Ecosystem Status?	Forecasting?	Upgradeable/ Adaptive	Question-based evaluation criterion	Statistical Foundation?	Reporting Protocol?	Pros	Cons
ıs y :o h	Table/graphic output that summarizes priorities for restoration (*i.e.*, degraded attributes in different geographic areas (reaches). Also reach-specific output of restoration potential, etc.	Pre-development and current conditions comparison to define natural limits and potential recovery.	Should be adaptable to different species in different areas. Probably requires much work.	No.	Statistical models are added to test hypothesis, linkages (correlation) and determine outcomes.	Standard output tables.	Step-by-step procedure. Provides measure of ecological status and biological performance but are species/ population specific (*e.g.*, salmon). Index of environmental/habitat correlates is useful. Reach and basin level analysis provides multi-scaled results and categorizes restoration potential.	Assessment is focused on biological performance of salmon species through various life stages. The EDT is not a holistic evaluation (*e.g.*, does not consider riparian areas, birds, recreation, etc.).

Aggregated Measure of Ecosystem Status?	Forecasting?	Upgradeable/ Adaptive	Question-based evaluation criterion	Statistical Foundation?	Reporting Protocol?	Pros	Cons
ummarizes e-support, ocial/cultural nd production alues using valuation iteria.	No.	Evaluation survey may be adapted to evaluate river systems at a variety of scales to evaluate ecological health rather than wetland importance. Requires understanding of ecological indicators, processes, functions, etc. – the survey would be developed from a working hypothesis of how a river functions.	Yes – a working guide is provided which can be used to evaluate wetlands. This consists of a series of surveys regarding project requirements and ecological function/ value of the wetland.	No – but a numerical rating of wetland functions is created in the survey/evaluation process – these ratings could be statistically evaluated for comparison purposes.	Yes – survey approach forces discussion when critical criteria are present.	Progressive approach underlines specific values and functions of a wetland. Provides a survey to rapidly determine value of a wetland. Critical criteria cause further evaluation. Provides an evaluation of 'significance' and a numerical 'relative rating' tool.	Evaluation criteria based on understanding of wetland functions and processes and relative significance to ecosystems, economics, etc. – based on working hypothesis of wetlands. Qualitative inputs based on professional opinions.

I.5 Missouri Resource Assessment Partnership (MoRAP) -(online: http:// www. cerc. usgs. gov/ morap/ defau

Approach/ Method Type	River System Features	Data Type	Scale	Data Inputs	Framework or Indicator Development Process?	Ecosystem Indicators?	Ecosystem Evaluation Criteria?
Missouri Resource Assessment Partnership (MoRAP) – Digital Data Development.	Missouri River basin.	Spatial data for integration to GIS = Maps.	Statewide assessment – multiple basins, sub-basin scales.	Individual projects are collecting a variety of data for assessment purposes.	GIS – multiple uses including input to ecosystem status evaluation.	Unclear – there is one project specifically delineating ecological land types (ELT).	Anything that can be mapped – hydrology, land use, biota, climate, historical development, disturbance, etc.

I.6 Queensland Government – Water Resource Plans (*e.g.*, Pioneer Valley) - http://www.nrm.qld.gov.au/wrp/

Approach/ Method Type	River System Features	Data Type	Scale	Data Inputs	Framework or Indicator Development Process?	Ecosystem Indicators?	Ecosyste Evaluati Criteria
Technical Advisory Panel (TAP), hydrological modelling and monitoring program used to assess ecological conditions using a risk assessment approach. Fundamentally based on the concept that changes in flow regime affect ecosystem conditions.	Multiple rivers in Queensland, Australia. Major problems associated with water extraction, agriculture, etc.	Qualitative/ Quantitative.	Multi-basin.	Hydrologic modelling (similar to RVA) at a daily time step, basin-wide, includes flow events, routing and accounts for diversions and day-to-day operations of weirs, etc. Also requires development of flow indicators, performance measures.	Yes – methodology for development of flow indicators and environmental flow performance measures (benchmarks for risk assessment). Framework for assessment based on understanding the hydrologic variability is key driver in protecting ecosystem.	Key flow indicators (*e.g.*, mean annual flow, variance, flow duration, flow exceedance, minimum flows); environmental flow measures (benchmarks for risk to ecology);environmental assessment criteria (supplemental to environmental flow performance measures (*e.g.*, water levels, fish passage, artificial flow variation, water quality, transfers, etc.).	Geomorphol hydraulic hal aquatic vegetation, riparian vegetation, v quality, macr invertebrates

asp)

ggregated leasure of cosystem Status?	Forecasting?	Upgradeable/ Adaptive	Question-based evaluation criterion	Statistical Foundation?	Reporting Protocol?	Pros	Cons
.	No.	Algorithms could be adapted to provide spatially derived ecological assessment criteria (*e.g.*, biota, habitats, climate, etc.)	No.	No – metrics can be derived using GIS algorithms.	No.	GIS approach to assessing resources is a useful step in assessing ecological status. Provides spatial data on multiple variables and scales.	GIS approach alone is insufficient to characterize ecological status – understanding of structure, function, processes, etc., is required to use spatial data as surrogate measure of ecological status.

oneer.html

	Aggregated Measure of Ecosystem Status?	Forecasting?	Upgradeable/ Adaptive	Question-based evaluation criterion	Statistical Foundation?	Reporting Protocol?	Pros	Cons
, t, er sh.	Benchmarks for flow analysis (no impact/impact); classification of changes (natural, water resources development or other non-water resources development factors); rating of magnitude of change (from indiscernible or natural to very major); ranked importance of water resources effects (*i.e.*, importance of maintaining structure or flow regime).	Yes – based on future alterations of flow (*e.g.*, diversions, reservoir augmentation, etc.).	Yes – indicators would have to be modified.	No.	Hydrological statistics are compared to benchmarks with an associated ecological/ geomorphologic risk.	Rating system is simple, could be applied to all basins.	Use of hydrological variability provides a basis for standardizing assessment. Risk assessment approach with environmental flow performance measures is sensible. RVA approach (Richter *et al.* 1997) could produce similar statistics as the hydrological model.	Development of benchmarks for potential risk could be difficult. Requires hydrological modelling

APPENDIX II

DATA AVAILABLE FOR ANALYSIS

DATA AVAILABLE FOR ANALYSIS

Much long-term data are available for analysis; the quality of these data is variable and should be assessed before any intensive analysis is begun. Many of the long-term data sets (*e.g.*, water quality) have been collected with good documentation and have followed standard protocols of collecting and processing. Much additional data has been collected by individual researchers and may or may not meet the standards required by the SSRB managers. Many of these data sets can be identified from the work documented in the reading list/bibliography listed in Appendix IX. There are many data gaps that were identified during this survey; they have been listed after the reach grade summary for each sub-basin in Appendix VII.

The major data sets have been itemized in the following list.

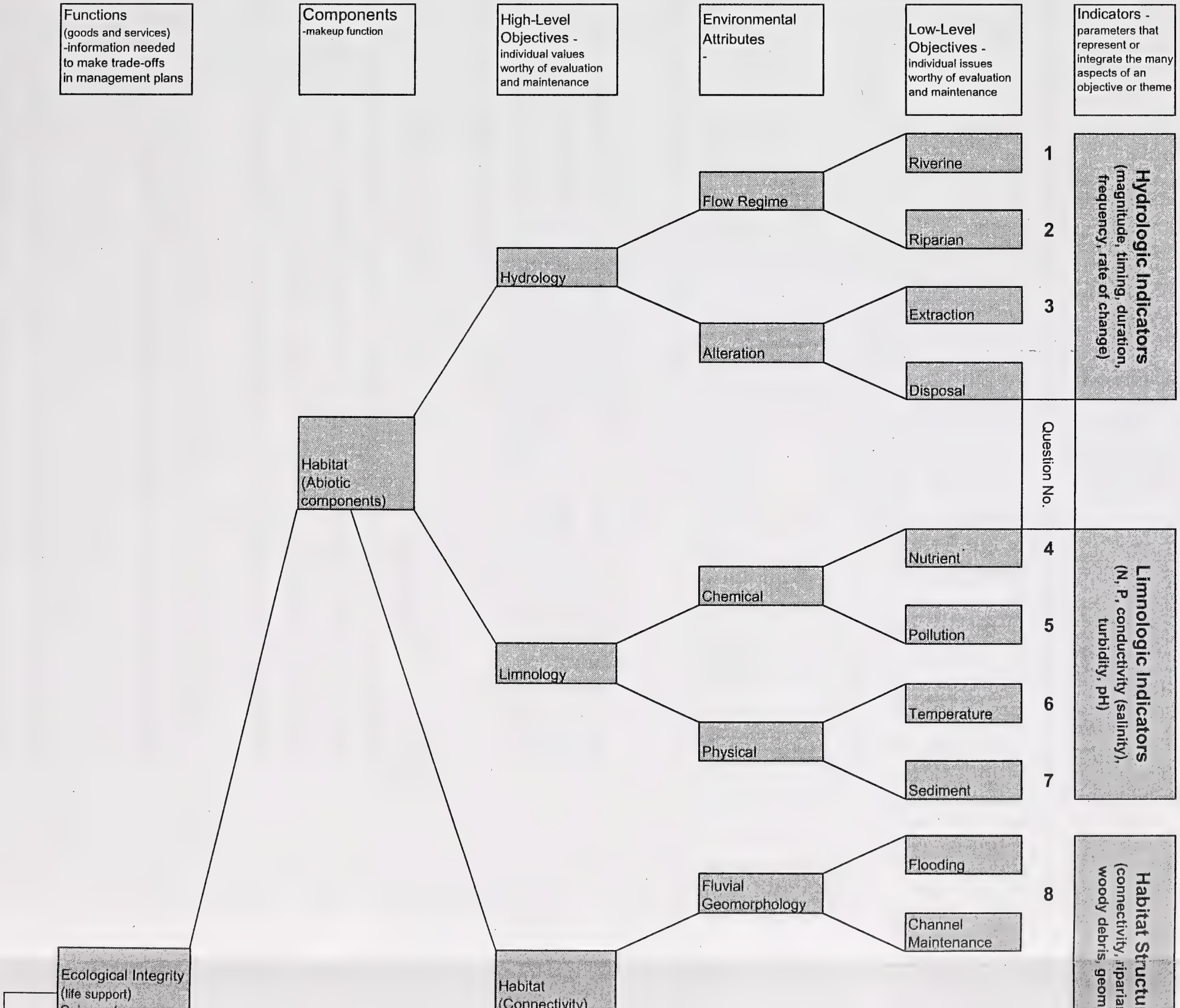
1. Environment Canada – climate data.
2. Fisheries and Oceans Canada – fisheries and fish habitat database for southern Alberta.
3. Alberta Sustainable Resource Development – fisheries management information system and IFN survey data.
4. Alberta Environment/Water Survey of Canada – hydrologic data for the SSRB.
5. Alberta Environment/Environment Canada – water quality database.
6. Alberta Environment – water release data from dams/impoundments of the SSRB.
7. Remote sensing data (NASA) – Landsat imagery (180 x 180 km maps), ASTER and other multispectral imaging sensors (higher resolution and greater definition), Indian Resource Survey panchromatic images at 1:50,000 scale, etc. These data can be used to build retrospective data sets of land use that can then be used for time series (change) analysis.
8. Alberta Agriculture, Food and Rural Development – irrigation extraction records and records of licenses issued.
9. Trout Unlimited has water temperature data; validation needed prior to any analysis.

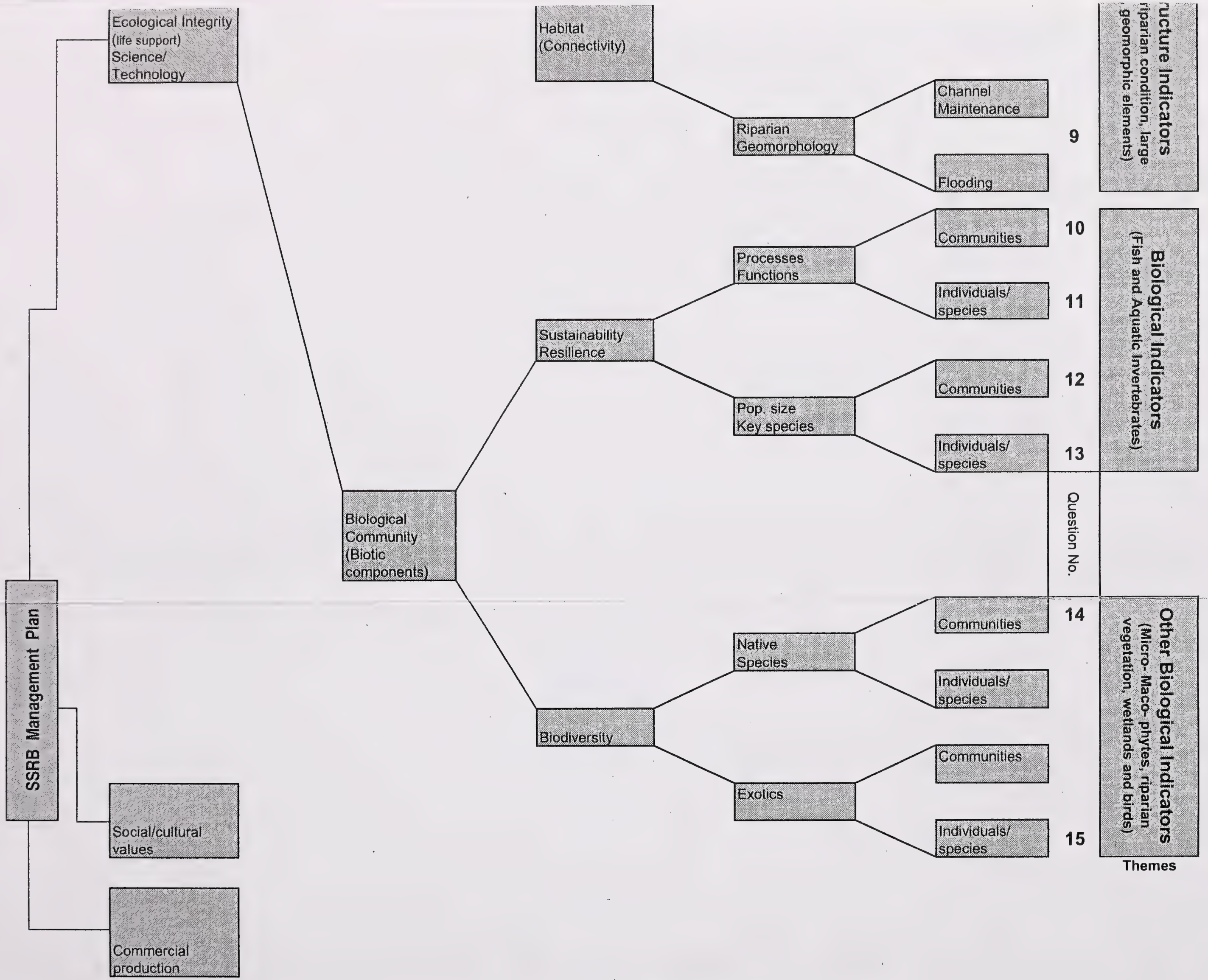
In addition to actual data sets, there are some models available that can be used to test hypotheses and generate data in areas with limited monitoring. These include: Irrigation District Model, Water Resources Management Model, and Water Temperature/Dissolved Oxygen Model (Red Deer River).

APPENDIX III

FRAMEWORK AND QUESTIONNAIRE USED AT WORKSHOPS

Figure III-1
The Interrelationships of Ecosystem Information That Could Be Considered When Developing a Riverine Management Plan





The boxes at the top that are not shaded are the terms used in this report to represent a specific hierarchical level in the framework.
The numbers in the second column from the right refer to the questions used in the workshops.
The low level objectives of this framework were used as a guide to the distribution of the 15 questions across the major themes.

QUESTIONNAIRE USED IN TECHNICAL WORKSHOPS

Although the results of these questionnaires are combined and no names are associated with any specific conclusion, the participants were asked to voluntarily add their names on the answer sheets in case further clarification of responses was required. At each session, prior to beginning the workshop, we reviewed the 15 questions and the overall ecosystem framework (Figure III-1). During this introductory session, it was affirmed that the watershed of each reach and the reach itself comprised an integral part of the sub-basin; however, this assessment and the questionnaire dealt only with the status of the mainstem within the reach, unless it was specifically stated otherwise.

In many of the questions, examples were provided for clarification. In an attempt not to 'lead' the respondents to a predetermined point of view, many of these examples, particularly the species names, were not specific to the SSRB region.

There were several questions of clarification that arose at the first workshop in Lethbridge. Those issues were noted and presented in the opening remarks at the subsequent two workshops; thus the information available was the same for all three workshops. No substantive additional issues arose in either of the latter two workshops.

The questionnaire was made up of 15 primary questions that required a categorical answer to the question and a categorical status of the trend during the past 5 to 10 years. In addition, we requested an indication as to whether or not the respondent considered the change due to water resource development or not. For all questions, the respondents could add notes to explain their view and for 11 of the 15 questions there were follow-up questions to further identify key issues.

In the following outline of the questionnaire makeup, the primary question is first, the follow-up (supplemental) question, if present, follows and then, in italics, the comments that were presented to the participants is last.

Question 1: The flow regime in all our study reaches has been altered by flood or hydro impoundments, irrigation diversions, etc. Relative to the flow regime do you consider this RIVERINE reach ecosystem to be: [select 1 of 6 response options]

What do you think are the main aspects of flow that affect this reach? (high/low water, mean, monthly flow, duration of flood, etc.)

No specific comments.

Question 2: The flow regime in all our study reaches have been altered by flood or hydro impoundments, irrigation diversions, etc. Relative to the flow regime, do you consider this RIPARIAN reach ecosystem to be: [select 1 of 6 response options]

No specific comments.

Question 3: Many land-use practices influence water availability (urban, agricultural practices, dugouts/farm dams, extraction, discharge, etc.). Do you feel land use in this watershed has left the flow: [select 1 of 6 response options]

What is the main factor affecting water availability in this reach? What is the main land use that impacts this watershed?

For this question the issues of forestry and slough drainage were discussed in addition to the examples listed. This question related to issues and concerns not necessarily on the mainstem.

Question 4: Rivers have a natural nutrient regime that is often controlled by the local geomorphology (pools, riffles, sand bars, islands, etc.). Alteration of flow and channelizing can reduce nutrient retention while runoff and disposal can enhance the nutrients in the system. Do you consider the nutrient regime in this reach to be: [select 1 of 6 response options]

This natural nutrient regime was referring to the organic/biological regime of nutrients, i.e., forest litter, etc. being carried and stored in the river, feeding the benthic community and the nutrients moving up the food chain. It did not refer to the natural nutrients in solution or suspension that feed the primary producers. For this question, the issue of irrigation return flows was discussed in addition to the examples listed. Also, it was decided to include the issue of contaminants as well as nutrients.

Question 5: Chemical composition of the water can be affected by point and non-point sources of pollution. Do you feel pollution in this watershed has left the water quality: [select 1 of 6 response options]

Please provide examples (industry, intensive livestock operations, pesticides, fertilizers, etc.)

For this question, after discussion, the group decided to consider the issues of biological (pathogen) contaminants such as Giardia lamblia / Cryptosporidium sp.).

Question 6: Temperature is a controlling influence in an aquatic ecosystem. Do you think alteration in water temperature have left this reach: [select 1 of 6 response options]

What factors have caused any +/- change (impoundment effects, reduced flow/ increased solar heating, deep water discharge, reduced cover, etc.)?

No specific comments.

Question 7: Alteration of flow can affect sediment distribution throughout the system by erosion, deposition, or changes in suspended sediments. Do you think the natural sedimentation regime in this reach is: [select 1 of 6 response options]

What has caused any change (impoundment, reduced high floods, soil erosion, reduced riparian cover, grazing, etc.)

No specific comments.

Question 8: Large river systems generally support good habitat for the native fish and benthic invertebrates of the region. Relative to fish and benthic invertebrates, do you consider the habitat of this reach to be: [select 1 of 6 response options]

What native fish inhabit this reach? What exotic fish?

No specific comments.

Question 9: Riparian zones of large river systems generally support good habitat for the native birds and mammals of the region. Relative to birds and mammals, do you consider the riparian habitat of this reach to be: [select 1 of 6 response options]

List the native birds and mammals that predominantly depend upon this riparian zone.

No specific comments.

Question 10: Terrestrialization (a shift from riparian to terrestrial vegetation) of the riparian zone is considered an indication of a shift of ecosystem dynamics. Is the riparian vegetation in this reach: [select 1 of 6 response options]

List the predominant riparian vegetation of this reach.

No specific comments.

Question 11: Natural riparian zones have high heterogeneity of various successional stages resulting from regular disturbances. Do you consider the successional stage of this riparian zone to be: [select 1 of 6 response options]

No specific comments.

Question 12: Flood pulsing is a key factor in the resilience of riverine/riparian communities. Annual timing, duration, and the rate of change are especially important in temperate regions where light and temperature also influence productivity and life cycles. Do you consider the cycle of flood pulsing and its effects on this reach communities to be: [select 1 of 6 response options]

The issue of what is a flood was discussed. This question refers to the annual sequence of high flood or discharge events and not to just the annual biggest flood event.

Question 13: Key species (ecologically dominant *i.e.*, wolf, carp) exert a dominant influence on ecosystems. Have the populations of these species been: [select 1 of 6 response options]

Has there been a change in key species? Please identify plant and animal species you consider key in both riparian and riverine zones.

The key species in this question was referring to the 'native' key (or ecologically dominant) species. Thus, if the dominant native plants have been replaced by Canada thistle[2] *and it is now dominating the system, the native would be considered to be in a heavily impacted or degraded state and not the thistle in an unchanged and improving trend.*

Question 14: Rivers and their riparian zones are biologically diverse; riparian 'forests' often create unique watershed habitats. Is the biodiversity of native plants and animals in this reach: [select 1 of 6 response options]

Please list rare, threatened, or endangered plants or animals you know of in this reach.

No specific comments.

Question 15: Exotics are common throughout most ecosystems and they often upset the ecosystems balance resulting in a loss of diversity. Do you consider exotic invasions have left this reach: [select 1 of 6 response options]

Please list the major exotics you know in this reach.

The workshop participants requested that exotics in this assessment refer only to non-native species, that in the view of the BJP, are not desirable and considered to be a nuisance. As an example, the rainbow trout in reach BW-03 have developed into an important sport fishery below Calgary. They are filling the niche once likely occupied by cutthroat and bull trout and are not considered a nuisance. On the other hand, the brook trout in the upper reaches of the southern tributaries of the Oldman River are considered to be detrimental to the existing bull trout population and are therefore noted as an exotic.

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[2] See Appendix VIII for the scientific names of the species listed in this report.

A general follow-up question for all participants: Please identify any other issues that, in your experience, are significant regarding the state of the SSRB ecosystem in this sub-basin. Can you identify any other key characteristics of the ecosystem that you feel should be included in an assessment of the SSRB?

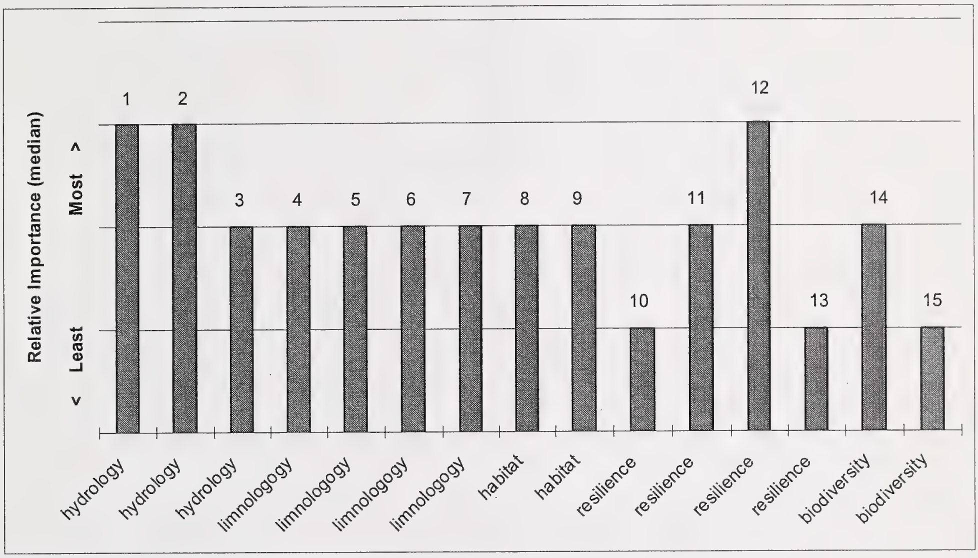
IMPORTANCE WEIGHTING SCHEME

The participants of each Technical Workshop were asked to rank the relative importance of each of the 15 questions or themes that comprise the questionnaire, with regards to the ultimate development of a management plan. The participants were requested to place five of the questions in each of three categories: Most Important, Important, and Less Important.

The responses (24 in total) were combined by taking the median value for each question (theme). The hydrology theme was considered the most important, with the biological themes generally being considered less important (Figure III-2). Questions 1 (hydrology), 2 (hydrology), and 12 (resilience related to hydrology) were considered the most important and they all related to floods and flooding of the system, both fluvial and riparian. Questions 10 (resilience), 13 (resilience), and 15 (biodiversity) were considered the least important and all related to the status of individual species or species groups.

These assessments of theme importance reflect importance as observed in ecosystem condition assessment literature. They also reflect the background and experience of the participants of the technical workshops.

Figure III-2
Relative Importance as Assessed by the Participants of the Technical Workshops



The numbers above the bars are the question numbers listed in Appendix III.

APPENDIX IV

SUB-BASIN REACHES AND ATLAS

SUB-BASIN REACHES AND ATLAS

The reaches of each sub-basin are those previously identified by AENV and ASRD staff and those delineated by Golder staff under the direction of AENV (shaded boxes). The watershed area of each reach and the length of streams (both permanent and intermittent) within the watershed are listed on the associated maps in this appendix.

Table IV-1
Red Deer River Reach Boundaries and Gauging Stations

Reach Boundaries	Reach Code	WSC Gauge	Gauge Location
Sundre gauging station downstream to Dickson Dam / Gleniffer Lake	RD-08	05CA001	near Sundre
Dickson Dam / Gleniffer Lake to upstream of Medicine River confluence	RD-07	05CB007	Dickson Dam
Medicine River confluence to upstream of Blindman River confluence	RD-06	05CC002	near Red Deer
Blindman River confluence to upstream of proposed SAWSP diversion site	RD-05	05CD004	near Nevis
Proposed SAWSP diversion site to upstream (western boundary) of Drumheller	RD-04	GRDBIG	near Big Valley
Western boundary of Drumheller to upstream of Dinosaur Provincial Park (includes Berry Creek)	RD-03	05CE001	near Drumheller
Western boundary of Dinosaur Provincial Park to upstream of Bindloss gauging station	RD-02	GRDJEN	near Jensen
Bindloss gauging station to Saskatchewan / Alberta border	RD-01	05CK004	near Bindloss

Table IV-2
Bow River Reach Boundaries and Gauging Stations

Reach Boundaries	Reach Code	WSC Gauge	Gauge Location
Bearspaw Dam downstream to WID Weir	BW-05	05BH004	Calgary
WID Weir to upstream of Highwood River confluence	BW-04	GBOWID	below WID Weir
Highwood River confluence to upstream of Carseland Weir	BW-03	05BM002	below Carseland Weir
Carseland Weir to upstream of Bassano Dam	BW-02	05BM002	below Carseland
Bassano Dam to Grand Forks (confluence of South Saskatchewan River	BW-01	05BM004	below Bassano

Table IV-3
South Saskatchewan River Reach Boundaries and Gauging Stations

Reach Boundaries	Reach Code	WSC Gauge	Gauge Location
Grand Forks to upstream of the Medicine Hat gauging station	SS-02	05AJ001	Medicine Hat
Medicine Hat gauging station to Saskatchewan / Alberta border	SS-01	05AK001	near Hwy 41

Table IV-4
Oldman River Reach Boundaries and Gauging Stations

Reach Boundaries	Reach Code	WSC Gauge	Gauge Location
The gauge at Waldron's Corner downstream to the Oldman Dam	OM-08	05AA023	Waldron's Corner
Oldman Dam to upstream of Pincher Creek confluence	OM-07	05AA024	near Brocket
Pincher Creek confluence to upstream of LNID Weir	OM-06	05AA024 + 05AA004	Brocket + Pincher
LNID Weir to upstream of Willow Creek confluence	OM-05	05AB007	near Ft. Macleod
Willow Creek confluence to upstream of Belly River	OM-04	05AD019	near Monarch
Belly River confluence to upstream of St. Mary River confluence	OM-03	05AD019 + GBEMOU	Monarch + Belly
St. Mary River confluence to upstream of Little Bow River confluence	OM-02	05AD007	near Lethbridge
Little Bow River confluence to Grand Forks (confluence South Saskatchewan River)	OM-01	05AG006	near Mouth

Table IV-5
Belly, St. Mary and Waterton Rivers Reach Boundaries and Gauging Stations

Reach Boundaries	Reach Code	WSC Gauge	Gauge Location
Belly River			
Upstream of the confluence of Mami Creek (near Hwy 800) downstream to the St. Mary Canal	BL-04	05AD005	near Mountainview
St. Mary Canal to 125 km upstream of Oldman River confluence	BL-03	05AD041	near Glenwood
125 km upstream of Oldman River confluence to upstream of Waterton River confluence	BL-02	05AD002	near Standoff
Waterton River confluence to the confluence with the Oldman River	BL-01	GBWCON	Waterton confluence
St. Mary River			
Upstream of Woolford Provincial Park downstream to St. Mary Dam	SM-03	05AE027	International Border
St. Mary Dam to 37 km upstream of the confluence with the Oldman River	SM-02	GSTDAM	St. Mary Dam
37 km upstream of the confluence with the Oldman River to the confluence with the Oldman River	SM-01	05AE006	near Lethbridge
Waterton River			
Road crossing about 12 km upstream of Waterton Reservoir downstream to Waterton Reservoir	WT-03	05AD003	near Waterton National Park
Waterton Reservoir to 45 km upstream of the Belly River confluence	WT-02	05AD026	Waterton Reservoir
45 km upstream of the Belly River confluence to the confluence with the Belly River	WT-01	05AD008	near Standoff

Figure IV-1
Map of the Red Deer River Sub-basin of the South Saskatchewan River Basin within Alberta

Watersheds are superimposed on a composite Landsat image (band 5). The reach and corresponding watersheds are marked using the same 'Reach Code' as identified in Table IV-1. Urban areas, roads (black dotted lines), and irrigation districts (white dotted boundaries) are marked for clarification. Only the major watercourses are displayed. In the watershed details table under the map, the two columns: Stream Length – Provincial Data; and, Stream Length – GIS Data refer to the length of all (permanent and intermittent) streams and the length of only permanent streams, respectively.

Note: The following map is presented in 11" x 17" format.

LEGEND

MAJOR ROADWAY
WATERSHED BOUNDARY
RIVERS AND STREAMS
IRRIGATION DISTRICT
GAUGE STATION

REFERENCE

Landsat 7 Imagery obtained from Natural Resources Canada and RGI Data.
Datum: NAD 83 Projection: UTM Zone 12

WATERSHED DETAILS

Reach	Area (square km)	Stream Length (km) (Provincial Data)	Stream Length (km) (GIS Data)
RD-01	2036.9	1823.9	499.7
RD-02	5823.2	5830.6	1512.7
RD-03	15557.4	13552.9	4350.3
RD-04	6373.1	6521.7	1543.2
RD-05	5051.8	3085.5	1185.5
RD-06	3955.1	3173.6	1020.2
RD-07	2642.2	3187.9	663.2
RD-08	2336.7	3104.9	635.2
Sundre Gauge	3222.1	4646.9	779.0

I:/2002/022-2355/GIS/Mapping/RedDeerRiver.mxd

PROJECT

South Saskatchewan River Basin - SORAC

TITLE

RED DEER RIVER WATERSHED

PROJECT No. 022-2355.2005			SCALE AS SHOWN	REV. 3
DESIGN	DC	16 Oct. 2002	FIGURE: IV-1	
GIS	RLP/CGA	24 Jan. 2003		
CHECK	DC	27 Jan. 2003		
REVIEW	DC	27 Jan. 2003		

Golder Associates
Calgary, Alberta

Figure IV-2
Map of the Bow River Sub-basin of the South Saskatchewan River System within Alberta (South Saskatchewan River Also Indicated on This Map)

Watersheds are superimposed on a composite Landsat image (band 5). The reach and corresponding watersheds are marked using the same 'Reach Code' as identified in Table IV-2. Urban areas, roads (black dotted lines), and irrigation districts (white dotted boundaries) are marked for clarification. Only the major watercourses are displayed. In the watershed details table under the map, the two columns: Stream Length – Provincial Data; and, Stream Length – GIS Data refer to the length of all (permanent and intermittent) streams and the length of only permanent streams, respectively.

Note: The following map is presented in 11" x 17" format.

LEGEND

- MAJOR ROADWAY
- WATERSHED BOUNDARY
- RIVERS AND STREAMS
- IRRIGATION DISTRICT
- GAUGE STATION

REFERENCE

Landsat 7 Imagery obtained from Natural Resources Canada and RGI Data.
Datum: NAD 83 Projection: UTM Zone 12

WATERSHED DETAILS

Reach	Area (square km)	Stream Length (km) (Provincial Data)	Stream Lengt (GIS Dat
SS-01	9517.7	9016.1	
SS-02	2630.6	2074.8	
BW-01	5229.3	3297.9	
BW-02	4294.5	3800.8	
BW-03	4396.6	7110.6	
BW-04	1139.2	1110.5	
BW-05	2368.0	3055.7	
Bearspaw Dam	7738.0	8571.3	

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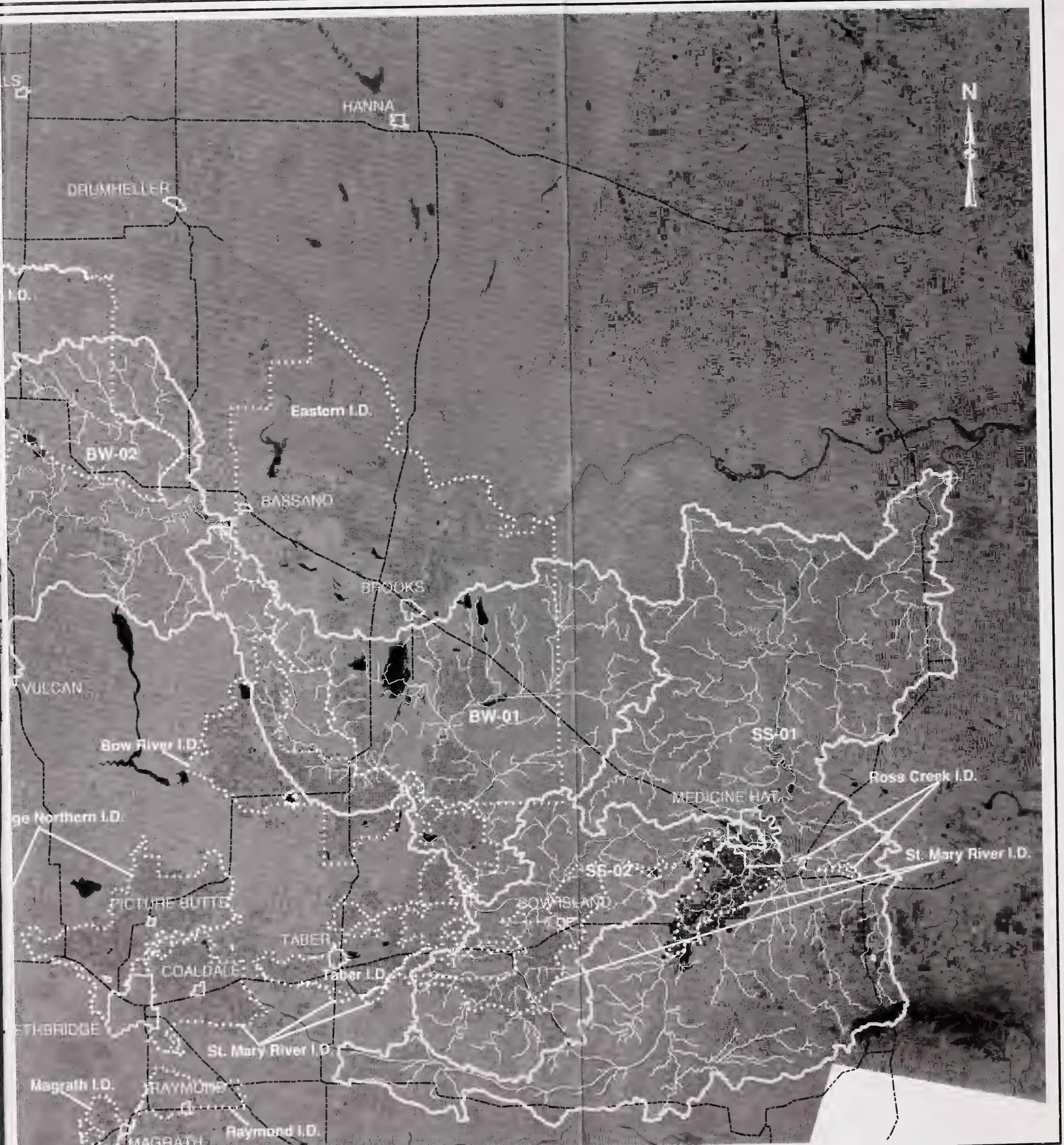


Length (km) (GIS Data)
2568.4
661.1
1336.0
1079.8
1146.2
330.8
602.8
1817.3

25 0 25
SCALE 1:1,300,000 KILOMETRES

PROJECT

South Saskatchewan River Basin - SORAC

TITLE **BOW RIVER & SOUTH SASKATCHEWAN RIVER WATERSHEDS**

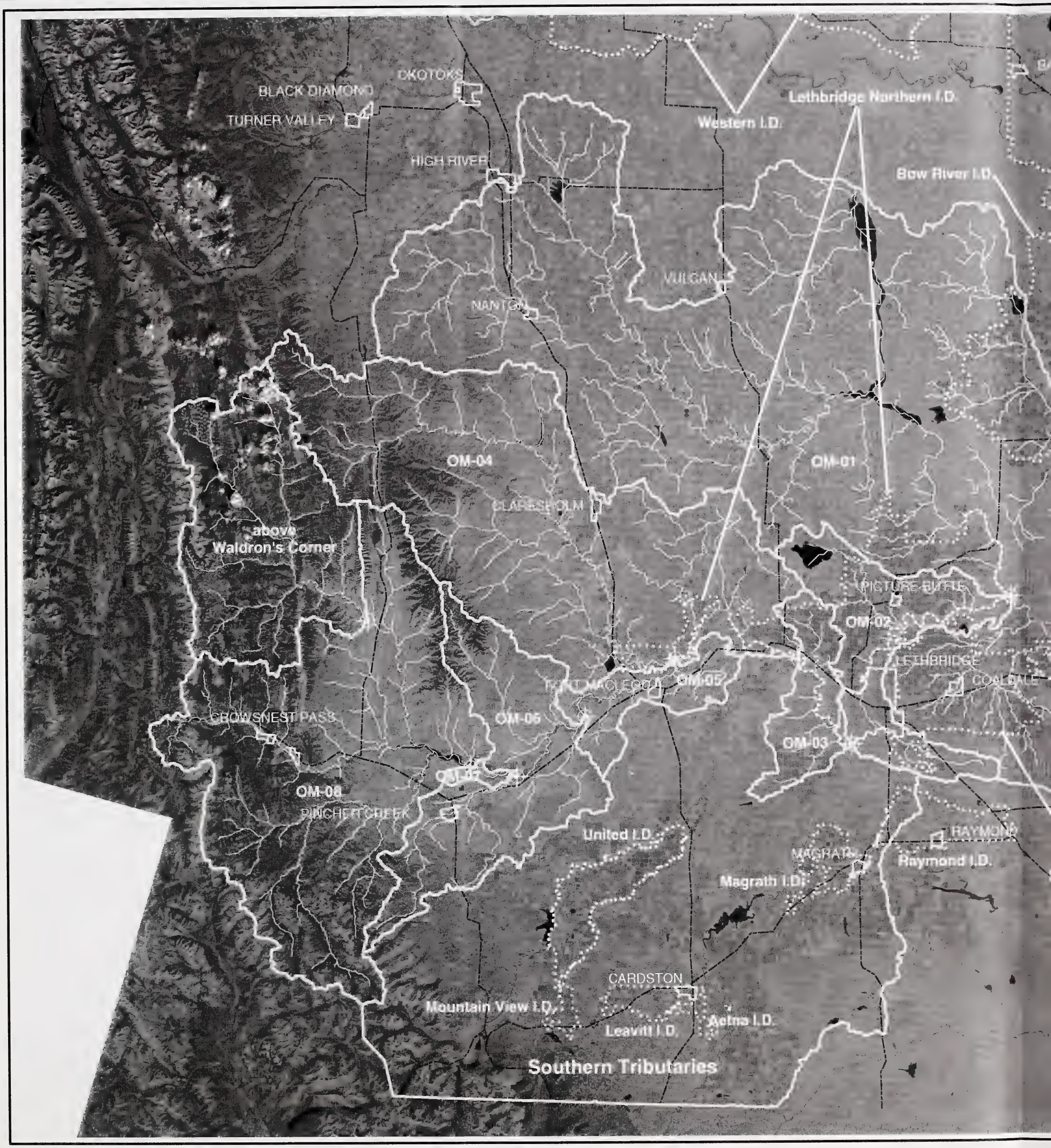
Golder Associates
Calgary, Alberta

PROJECT No. 022-2355.2005			SCALE AS SHOWN	REV. 3
DESIGN	DC	16 Oct. 2002	**FIGURE: IV-2**	
GIS	RLP/CGA	24 Jan. 2003		
CHECK	DC	27 Jan. 2003		
REVIEW	DC	27 Jan. 2003		

Figure IV-3
Map of the Oldman River Sub-basin of the South Saskatchewan River System within Alberta (South Saskatchewan River and Outline of the Southern Tributaries Also Indicated on This Map)

Watersheds are superimposed on a composite Landsat image (band 5). The reach and corresponding watersheds are marked using the same 'Reach Code' as identified in Table IV-3. Urban areas, roads (black dotted lines), and irrigation districts (white dotted boundaries) are marked for clarification. Only the major watercourses are displayed. In the watershed details table under the map, the two columns: Stream Length – Provincial Data; and, Stream Length – GIS Data refer to the length of all (permanent and intermittent) streams and the length of only permanent streams, respectively.

Note: The following map is presented in 11" x 17" format.



LEGEND

- MAJOR ROADWAY
- WATERSHED BOUNDARY
- RIVERS AND STREAMS
- IRRIGATION DISTRICT
- GAUGE STATION

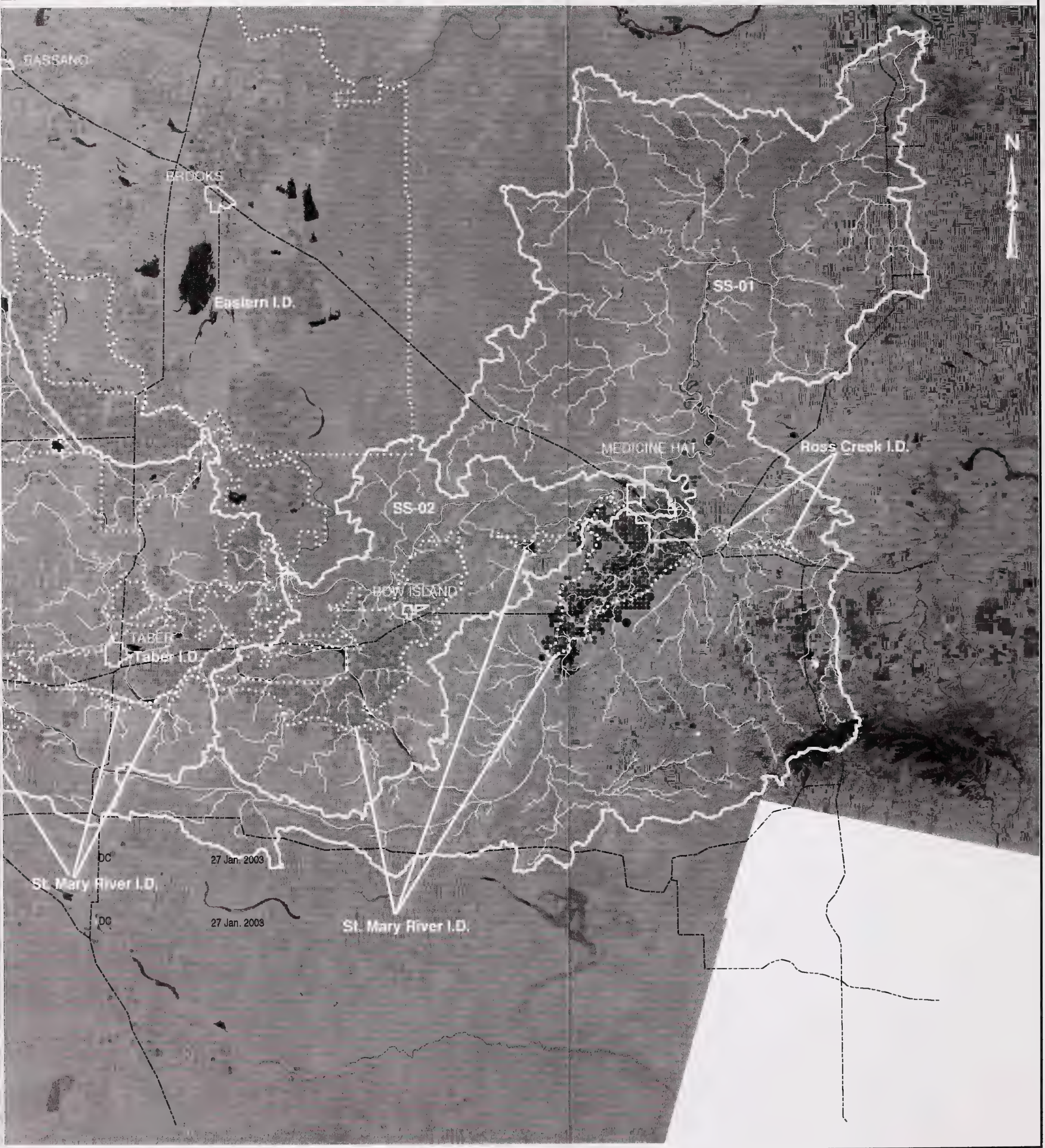
REFERENCE

Landsat 7 Imagery obtained from Natural Resources Canada and RGI Data.
Datum: NAD 83 Projection: UTM Zone 12

WATERSHED DETAILS

Reach	Area (square km)	Stream Length (km) (Provincial Data)	Stream Length (km) (GIS Data)
SS-01	9517.7	9016.1	2568.4
SS-02	2630.6	2074.8	661.1
OM-01	10241.9	6287.1	2698.8
OM-02	827.8	823.5	213.9
OM-03	381.7	319.0	111.3
OM-04	3309.8	4510.5	880.1
OM-05	344.2	216.9	95.5
OM-06	1166.2	1799.8	316.1
OM-07	35.0	46.9	12.0
OM-08	2932.5	5381.4	746.8
Waldron's Corner	1441.9	3334.9	326.0

I:/2002/022-2355/GIS/Mapping/OldmanRiver.mxd



25 0 25

SCALE 1:1,000,000 KILOMETRES

PROJECT

South Saskatchewan River Basin - SORAC

TITLE **OLDMAN RIVER & SOUTH SASKATCHEWAN RIVER WATERSHEDS**

Golder Associates
Calgary, Alberta

PROJECT No. 022-2355.2005			SCALE AS SHOWN	REV. 3
DESIGN	DC	16 Oct. 2002	**FIGURE: IV-3**	
GIS	RLP/CGA	24 Jan. 2003		
CHECK	DC	27 Jan. 2003		
REVIEW	DC	27 Jan. 2003		

Figure IV-4
Map of the Southern Tributaries (St. Mary, Belly, and Waterton Rivers) of the Oldman River Sub-basin of the South Saskatchewan River Basin within Alberta

Watersheds are superimposed on a composite Landsat image (band 5). The reach and corresponding watersheds are marked using the same 'Reach Code' as identified in Table IV-4. Urban areas, roads (black dotted lines), and irrigation districts (white dotted boundaries) are marked for clarification. Only the major watercourses are displayed. In the watershed details table under the map, the two columns: Stream Length – Provincial Data; and, Stream Length – GIS Data refer to the length of all (permanent and intermittent) streams and the length of only permanent streams, respectively.

Note: The following map is presented in 11" x 17" format.

LEGEND

- MAJOR ROADWAY
- WATERSHED BOUNDARY
- RIVERS AND STREAMS
- IRRIGATION DISTRICT
- GAUGE STATION

REFERENCE

Landsat 7 Imagery obtained from Natural Resources Canada and RGI Data.
Datum: NAD 83 Projection: UTM Zone 12

WATERSHED DETAILS

Reach	Area (square km)	Stream Length (km) Provincial Data	Stream Length (km) (GIS Data)
WT-01	108.0	175.9	40.4
WT-02	366.3	523.0	103.4
WT-03	485.2	760.4	152.7
Road Crossing	562.0	858.7	137.3
SM-01	1070.7	1518.7	322.4
SM-02	346.6	618.5	115.6
SM-03	519.6	781.7	136.6
Woolford Park	500.1	713.9	128.6
BL-01	659.6	655.7	208.7
BL-02	653.1	1319.3	199.2
BL-03	36.1	86.0	14.2
BL-04	121.5	205.8	33.2
Mami Creek	247.3	416.2	62.2

I:/2002/022-2355/GIS/Mapping/SouthernTribs.mxd

10 0 10

SCALE 1:450,000 KILOMETRES

PROJECT

South Saskatchewan River Basin - SORAC

TITLE

SOUTHERN TRIBUTARIES of the OLDMAN RIVER
Watersheds of Belly, St. Mary, and Waterton Rivers

Golder Associates Calgary, Alberta	PROJECT No. 022-2355.2005			SCALE AS SHOWN REV. 3
	DESIGN	DC	16 Oct. 2002	**FIGURE: IV-4**
	GIS	RLP/CGA	24 Jan. 2003	
	CHECK	DC	27 Jan. 2003	
	REVIEW	DC	27 Jan. 2003	

APPENDIX V

LIST OF ATTENDEES (BY MEETING)

LIST OF ATTENDEES (BY MEETING)

A list of invitees was compiled by AENV staff, those who attended are highlighted by shading in the following tables.

Lethbridge - Sub-Basin Technical Workshop:	Oct. 22, 2002
Jill Sorensen, Facilitator, Golder Associates Ltd.	jsorensen@golder.com
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Calgary – Sub-Basin Technical Workshop:	Oct. 23, 2002
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Red Deer – Sub-Basin Technical Workshop:	Oct. 24, 2002
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Best Judgment Panel (BJP)	Nov. 6, 2002
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APPENDIX VI

TECHNICAL WORKSHOP RESPONSES BY REACH AND THEME

TECHNICAL WORKSHOP RESPONSES BY REACH AND THEME

The value for a reach and question combination is the median value of the individual grade-responses received for that combination. Any combinations that had no responses are indicated by a solid black box. The numerical values (0 to -3) correspond to the grade responses: Unchanged / Recovered (0), Moderate Impact (-1), Heavy Impact (-2), and Degraded (-3).

Red Deer River Technical Workshop – October 24, 2002

Question		Reach							
Theme	No	RD-01	RD-02	RD-03	RD-04	RD-05	RD-06	RD-07	RD-08
Hydrology	1	-1	-1	-1	-1	-1	-1	-1	0
Hydrology	2	-1	-1	-1	-1	-1	-1	-1	-1
Hydrology	3	-1	-1	-1	-2	-2	-2	-2	-1
Limnology	4	-1.5	-1.5	-2	-2	-2	-2	-2	-1
Limnology	5	-1	-1	-2	-2	-2	-2	-2	-1
Limnology	6	0	0	-0.5	0	-1	-1	-1.5	0
Limnology	7	-1	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1
Habitat Structure	8	-1	-1	-1	-1	-1	-1	-2	-1
Habitat Structure	9	-1	-1	-1	-1	-1	-1	-1	-1
Resilience	10	-0.5	-0.5	-1	-0.5	-1	-1	-1	0
Resilience	11	-1	-1	-1	-1	-1	-1	-1	0
Resilience	12	-1	-1	-1	-1	-1	-1	-1	0
Resilience	13	-1	-1	-1	-1	-1	-1	-2	-0.5
Biodiversity	14	-1	-1	-1	-1	-1	-1	-2	-0.5
Biodiversity	15	-0.5	-0.5	-0.5	-0.5	-0.5	-1.5	-1	-1.5

Bow River and South Saskatchewan River Technical Workshop – October 23, 2002

Question		Reach						
Theme	No	BW-01	BW-02	BW-03	BW-04	BW-05	SS-01	SS-02
Hydrology	1	-3.0	-2.0	-1.0	-2.0	-2.0	-1.0	-1.0
Hydrology	2	-3.0	-1.0	-1.0	-1.0	-2.0	-1.0	-1.0
Hydrology	3	-1.0	0.0	0.0	-1.0	-1.0	0.0	0.0
Limnology	4	-1.0	-1.5	-1.5	-2.0	-0.5	-0.5	-0.5
Limnology	5	0.0	-1.0	-1.0	-1.5	-0.5	-1.0	-0.5
Limnology	6	-2.0	-1.5	-1.0	-1.0	-0.5	-1.0	-1.0
Limnology	7	-2.0	-1.0	-1.0	-2.0	-2.0	-1.0	-1.0
Habitat Structure	8	-3.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Habitat Structure	9	-1.0		-1.0			-1.0	-1.0
Resilience	10	-2.0	-1.5	-1.0	-2.5	-2.0	-1.0	-1.0
Resilience	11	-2.5	-1.0	-1.0	-2.0	-2.0	-1.0	-1.0
Resilience	12	-2.0	-1.0	-1.0	-1.5	-1.5	-1.0	-1.0
Resilience	13	-2.5	-1.5	-1.5	-1.5	-1.0	-1.0	-1.0
Biodiversity	14	-2.5	-1.0	-1.0			-1.0	-1.0
Biodiversity	15	0.0	-1.0	-1.0	-1.0	-1.0	-0.5	-0.5

Oldman River and Southern Tributaries of the Oldman River
Technical Workshop – October 22, 2002

Oldman River

Question		Reach							
Theme	No	OM-01	OM-02	OM-03	OM-04	OM-05	OM-06	OM-07	OM-08
Hydrology	1	-1	-1	-1	-1	-1	-1	-1	0
Hydrology	2	-1	-1	-1	-1	-1	-1	-1	0
Hydrology	3	-1	-1	-1	-1	-1	-1	-1	-0.5
Limnology	4	-1	-1	-1	-1	-1	-1	-1	-0.5
Limnology	5	-1	-1	-1	-1	-1	-1	-1	0
Limnology	6	-1	-1	-1	-1	-1	-1	-1	0
Limnology	7	-1	-1	-1	-1	-1	-1	-1	-0.5
Habitat Structure	8	-1	-1	-1	-1	-2	-2	-2	-2
Habitat Structure	9	-2	-1	-1	-1	-1	-0.5	-1	0
Resilience	10	-2	-1.5	-1.5	-2	-1	0	-0.5	0
Resilience	11	-2	-2	-1	-1	-1	-1	-1	0
Resilience	12	-1.5	-1.5	-1	-1.5	-1	-1	-1	-1
Resilience	13	-2	-2	-2	-2	-2	-2	-2	-2
Biodiversity	14	-2	-2	-2	-2	-1	-1	-1	-1
Biodiversity	15	-2	-1.5	-1	-1	-1	-1	-1	-1

Southern Tributaries of the Oldman River (SM – St. Mary, BL – Belly, WT – Waterton)

Question		Reach									
Theme	No	SM-01	SM-02	SM-03	BL-01	BL-02	BL-03	BL-04	WT-01	WT-02	WT-03
Hydrology	1	-2.5	-2	-0.5	-2	-1	-1	0	-2	-2	0
Hydrology	2	-3	-3	-1	-2	-1	-1	0	-2	-2	0
Hydrology	3	-1	-1	0	-1	-1	-1	0	-1	-1	-0.5
Limnology	4	-1	-1	0	-1	-1	-1	-0.5	-1	-1	0
Limnology	5	-1	-1	0	-1	-1	-1	0	-1	-0.5	0
Limnology	6	-2	-2	0	-2	-1	-1	-1	-1.5	-1	0
Limnology	7	-2	-1	0	-1	-1	-1	0	-1	-1	0
Habitat Structure	8	-2	-2	-0.5	-2	-1.5	-1.5	-1	-1.5	-1	0
Habitat Structure	9	-3	-3	0	-2	-1	-1	0	-1.5	-1	0
Resilience	10	-3	-3	-1	-1.5	-1	-1	0	-2	-1	0
Resilience	11	-1	-1	0	-1	-1	-1	0	-1	-1	0
Resilience	12	-2	-2	0	-1	-1	0	0	-1	-1	0
Resilience	13	-3	-3	-1	-2	-1		-1	-2	-2	-1.5
Biodiversity	14	-1.5	-2	-1	-0.5	-0.5	-1	-1	-1.5	-1	0
Biodiversity	15	-2	-2	-1	-1	-1	-0.5	-0.5	-1	-1	0

APPENDIX VII

STRATEGIC OVERVIEW OF RIPARIAN AND AQUATIC CONDITION (SORAC) BY SUB-BASIN AND REACH

STRATEGIC OVERVIEW OF RIPARIAN AND AQUATIC CONDITION (SORAC) BY SUB-BASIN AND REACH

These reach summaries provide the final grade assigned by the BJP which is indicated by the position of the trend pointer. The 5- to 10- year trend indicator points up, down, or sideways representing an improving, declining, or stable trend. The reach codes are defined in Tables IV-1 to IV-4 and reach watersheds are delineated in Figures IV-1 to IV-4. The reach summaries have been ordered upstream to downstream. The technical workshops provided a first opinion with key issues of the ecological condition assessment; these data were summarized and presented to the BJP who discussed the reach and provided a consensus assessment. In the majority of reaches the BJP consensus matched the average response derived from the workshop; in no reach did it change by more than a single category.

Participants at the workshops were asked to identify data gaps they considered hindered their ability to confidently answer the questions and that would be necessary to develop quantitative guidelines for a management plan for the SSRB. The key items are listed at the end of the summary for each sub-basin.

Hydrographs for individual reaches of each sub-basin were made available by AENV. The naturalized flow is a modelled data set and is often more extensive than that for the recorded or regulated flow. The recorded flow has variable coverage with some reaches having no available data or incomplete data (*e.g.*, for the Red Deer River see RD-02, RD-04, RD-05, and RD-08).

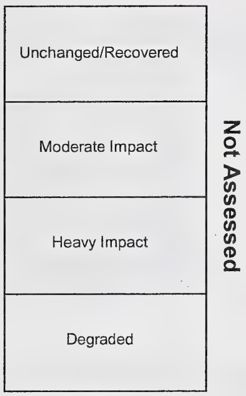
In the header for each reach assessment table some basic watershed parameters have been provided. Included are: watershed area in km^2 , watershed area as a percentage of the entire sub-basin, length of all streams in the reach-watershed in km, and the stream density in km of stream/km^2 of the watershed.

Red Deer River sub-basin

River: Red Deer River
Reach: Headwaters
Consensus condition: n/a

Watershed Area (%): 3222.1 km^2 (7%)
Streams – linear (density): 4646.9 km (1.4)

Red Deer River - Headwaters



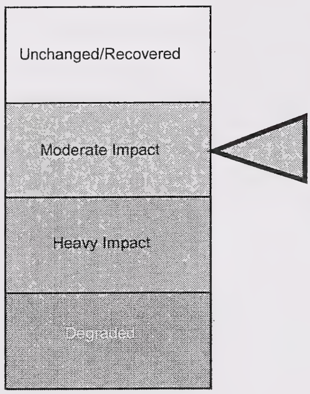
Issues:

1. The group of reaches above the WSC gauge in Sundre was not included in this assessment.
2. This stretch of river is relatively unaltered by impoundments on the mainstem or land use in the watershed.
3. Forestry is the major land use in this watershed; the highest headwaters are protected by Banff National Park.
4. The water quality in this region is good as it has not been influenced by any major sources of pollutants. Little water is removed in these reaches.

River: Red Deer River
Reach: No. 8
Consensus condition: Moderate Impact

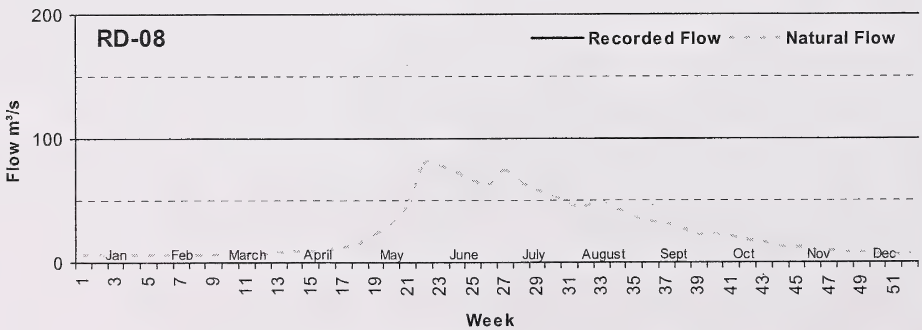
Watershed Area (%): 2336.7 km^2 (5%)
Streams – linear (density): 3104.9 km (1.3)

Red Deer River - Reach #8



Issues:

1. This reach includes the Red Deer River from the WSC gauge in Sundre downstream to Dickson Dam (Gleniffer Lake). There are no major industries, diversions or effluent outfalls within this reach.
2. Pipeline (hydrocarbons) crossings have been exposed by high flood events.
3. Light agriculture and forestry clearing is affecting the floodplain and river bank stabilization. Future encroachment onto the floodplain by agriculture and urban development (acreage lots) will increasingly become a significant issue as the floodplain in this reach tends to be unstable and dynamic.
4. Native bull trout have declined and are being replaced by exotic introductions of brown and brook trout.
5. Key species is whitefish.
6. Exotics[3] include brown and brook trout.



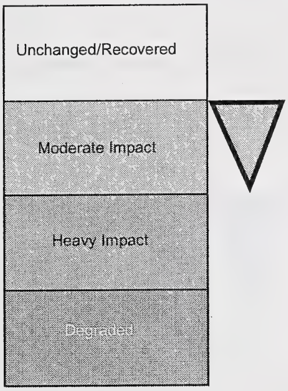
Natural Flows (1983 - 1995) No Recorded Flows

[3] See Appendix III (explanation for question 15) for definition of exotic and its use in this assessment.

River: Red Deer River
Reach: No. 7
Consensus condition: Moderate Impact

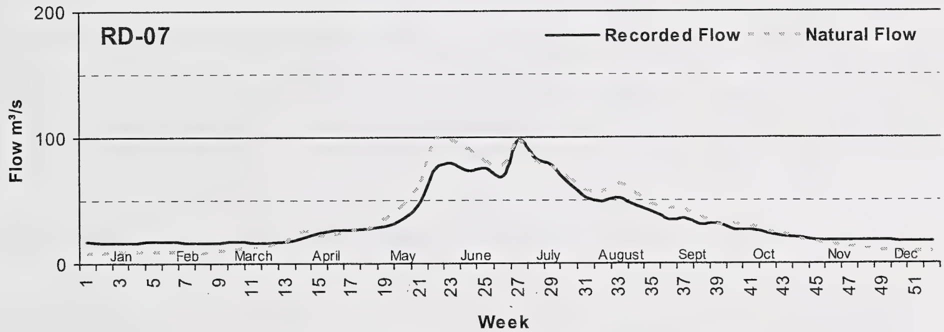
Watershed Area (%): 2642.2 km^2 (6%)
Streams – linear (density): 3187.9 km (1.2)

Red Deer River - Reach #7



Issues:

1. This reach includes the Red Deer River from Dickson Dam (Gleniffer Lake) downstream to the confluence of the Medicine River. The watershed includes the Little Red Deer River as the major tributary. The influence of Dickson Dam is most notable immediately downstream of the dam.



Natural Flows (1983 - 1995) Recorded Flows (1984 - 2001)

Note: The hydrograph for RD-07 has the recorded flows for gauge 05CB007 and the Dickson Dam spillway combined.

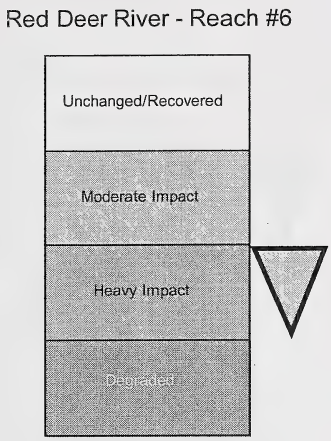
2. Dickson Dam is the largest impact on the river:
   - increased scouring and bank erosion immediately below the dam;
   - enhanced flows in winter, delayed winter cooling and spring warming and lower summer temperatures in some of the reach;
   - mountain whitefish continue to be the dominant species with populations increasing;
   - phytoplankton and attached (epilithic) algae have increased downstream of dam;
   - reduced diurnal variation in temperature; and,

- benthic invertebrates: worms and midges have increased while mayflies and stoneflies have declined since the dam was built.

3. Extensive livestock operations (cow-calf ranching); reduction of wetlands/drainage.
4. Agricultural run-off and water quality issues from the Little Red Deer River.
5. Sediment entrapment in the dam may lead to a decrease in sediment transported below dam.
6. Key species include brown trout and mountain whitefish.
7. Exotics include Canada thistle and smooth brome grass.
8. Exotics also comprise riparian vegetation, but a lack of expertise on the panel precluded detailed comment.

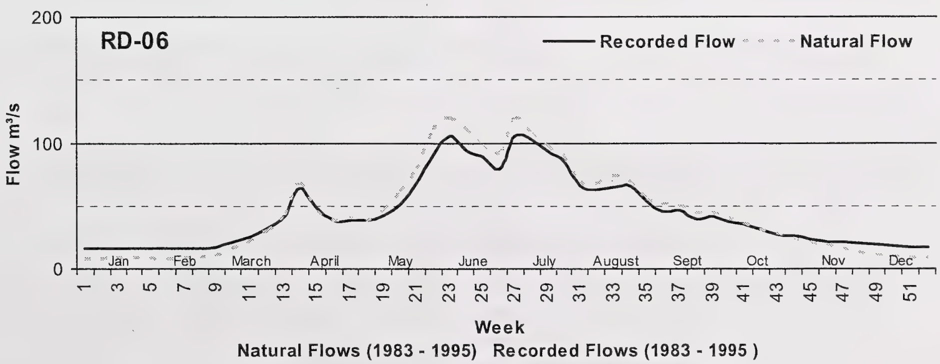
River: Red Deer River
Reach: No. 6
Consensus condition: Heavy Impact

Watershed Area (%): 3955.1 km^2 (8%)
Streams – linear (density): 3173.6 km (0.8)



Issues:

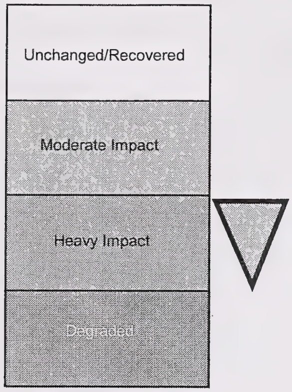
1. This reach includes the Red Deer River from the confluence of the Medicine River to the confluence of the Blindman River. The watershed includes the Medicine River and Sylvan Lake.
2. Dickson Dam has only a moderate impact on the riparian and riverine biodiversity of this reach.
3. Populations of phytoplankton and attached (epilithic) algae have increased downstream of the dam.
4. Increased municipal water diversion to the City of Red Deer and other municipalities.
5. Urban influences include sewage and stormwater runoff.
6. Industrial uses include impacts from hydrocarbon exploration and production.
7. Extensive livestock operations (cow-calf ranching), grazing, reduction of wetlands/drainage and runoff from Medicine River all degrade water quality.
8. Soil erosion and reduced bank cover.
9. Key species include mountain whitefish and walleye (seasonally).
10. Exotics include Canada thistle and smooth brome grass.



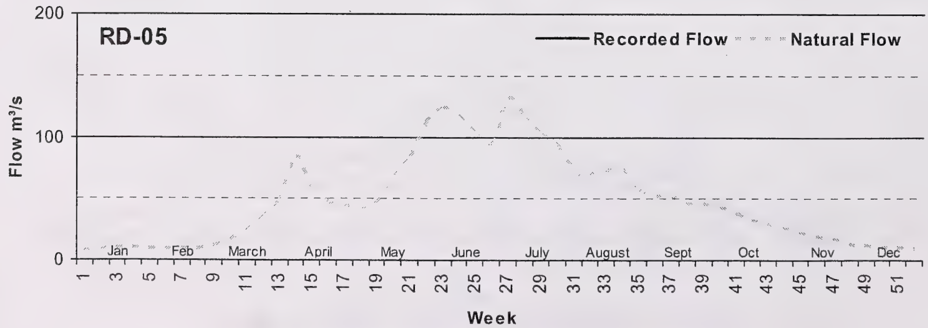
River: Red Deer River
Reach: No. 5
Consensus condition: Heavy Impact

Watershed Area (%): 5051.8 km^2 (11%)
Streams – linear (density): 3085.5 km (0.6)

Red Deer River - Reach #5



Issues:
1. This reach includes the Red Deer River from the confluence of the Blindman River to the site of the proposed Special Areas Water Supply Plan (SAWSP) diversion. This diversion is proposed to be up to 7 m^3/s. The watershed includes the Blindman River and Gull and Buffalo lakes.
2. Increased local water diversions, including at the Prentiss and Joffre petrochemical plants, and the Buffalo Lake diversion.
3. High temperature and low dissolved oxygen are sometimes an issue.
4. Extensive livestock operations, grazing, reduction of wetlands/drainage and runoff from Blindman River.
5. Nutrient enrichment from the City of Red Deer as the sewage treatment plant has yet to be upgraded. Phase I of upgrade completed in 2002, entire project to be completed by 2006.
6. Reduced peak flow results in increased sediment build-up in the lower reaches (little scour). May also be leading to establishment of floodplain willows.
7. Key species include goldeye and walleye.
8. Exotics include Canada thistle and smooth brome grass.

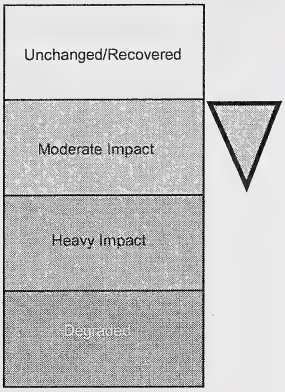


Natural Flows (1983 - 1995) No Recorded Flows

River: Red Deer River
Reach: No. 4
Consensus condition: Moderate Impact

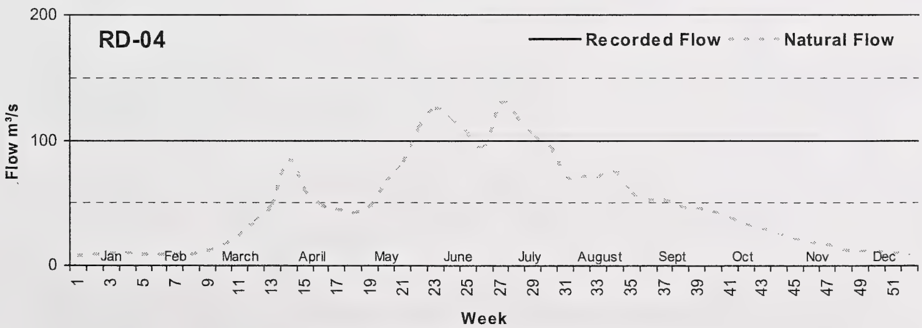
Watershed Area (%): 6373.1 km^2 (14%)
Streams – linear (density): 6521.7 km (1.0)

Red Deer River - Reach #4



Issues:

1. This reach includes the Red Deer River from the site of the proposed SAWSP diversion downstream to the western boundary of Drumheller.
2. Loss of peak flows, due to the dam, could result in long-term build up of sediment and macrophytes in the reach. May also be leading to establishment of floodplain willows.
3. Municipal and agricultural influences include nutrients from sewage, stormwater runoff, and biological contaminants (*Giardia lamblia / Cryptosporidium sp.*).
4. Extensive livestock operations (cow-calf operations), grazing and reduction of wetlands/drainage.
5. Industrial uses including oil and gas operations.
6. Key species include mountain whitefish and goldeye.
7. Exotics include purple loosestrife, Canada thistle, and smooth brome grass.

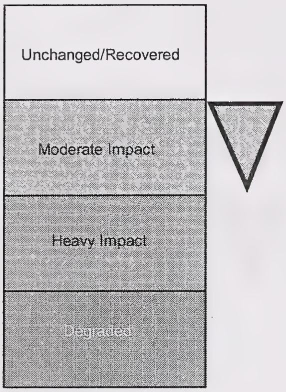


Natural Flows (1983 - 1995) No Recorded Flows

River: Red Deer River
Reach: No. 3
Consensus condition: Moderate Impact

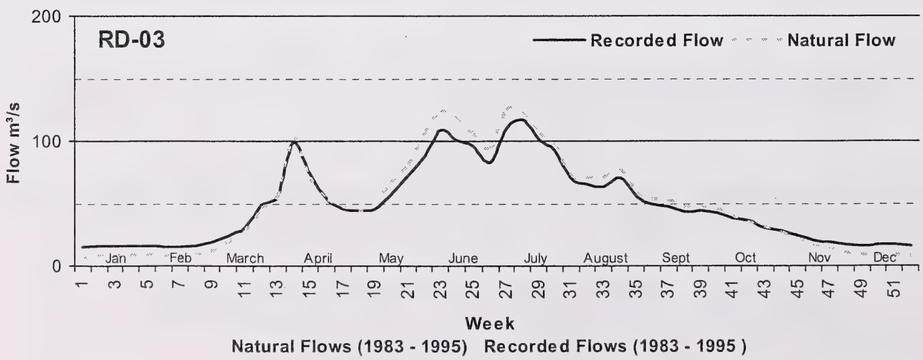
Watershed Area (%): 15557.4 km^2 (25%)
Streams – linear (density): 13552.9 km (0.9)

Red Deer River - Reach #3



Issues:

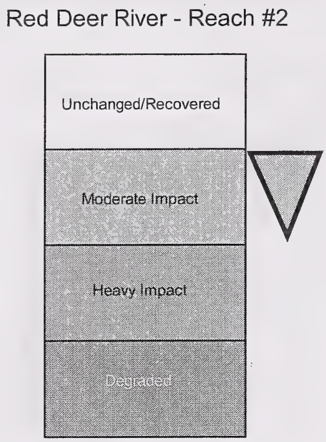
1. This reach includes the Red Deer River from the western boundary of Drumheller to the western boundary of Dinosaur Provincial Park (including the Berry Creek watershed). The watershed also includes three small lakes, Hand Hills, Little Fish, and Coleman, and the Crawling Valley Reservoir that receives trans-basin irrigation water from the Bow River.
2. Higher than normal winter flows are considered a benefit in this reach (improves winter dissolved oxygen levels); however, higher winter flows can be detrimental to wildlife, *e.g.*, beaver.
3. Return flows from the Eastern Irrigation District (EID) and Western Irrigation District (WID) are water sources from the Bow River that increase the volume and decrease the water quality of the Red Deer River.
4. Increased municipal water diversions to Drumheller and sewage effluent were identified as growing problems.



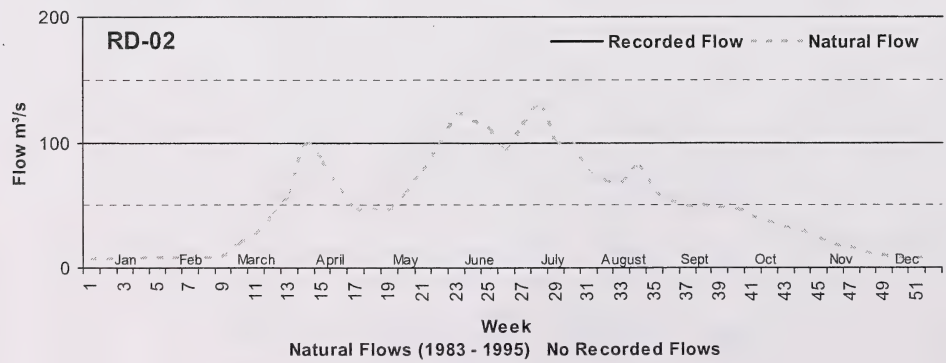
5. Urban influences include sewage and stormwater runoff as point and non-point sources of pollution.
6. Increases in invertebrates downstream due to enrichment by treated wastewater leading to changes in biodiversity.
7. Reduction of wetlands in watershed through drainage.
8. Possible stability in succession of riparian vegetation (slow change).
9. Key species include goldeye, walleye and sauger.
10. Exotics include purple loosestrife, Canada thistle, and smooth brome grass.

River: Red Deer River
Reach: No. 2
Consensus condition: Moderate Impact

Watershed Area (%): 5823.2 km^2 (12%)
Streams – linear (density): 5830.6 km (1.0)

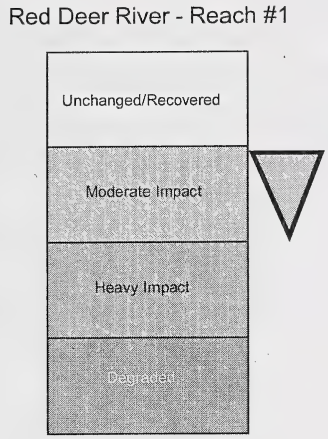


Issues:
1. This reach includes the Red Deer River from the western boundary of Dinosaur Provincial Park to the Bindloss gauging station.
2. Dickson Dam has had significant impacts on the two lowest reaches by reducing the highest flood peaks. Before the dam, the river had a shifting sand substrate. Since the dam, the river bed has stabilized and sand bars have become colonized by willows. There are also reductions in moderate to low flood peaks, which have resulted in a decrease in cottonwood recruitment.
3. Reduction in forest cover, which leads to less diversity in wildlife.
4. Extensive livestock operations (cow-calf operations), water extraction, grazing and wintering of cattle in riparian zones.
5. Oil and gas operations and pipeline crossings.
6. Key species include cottonwood, goldeye, walleye and sauger.
7. Exotics include Canada thistle and smooth brome grass.



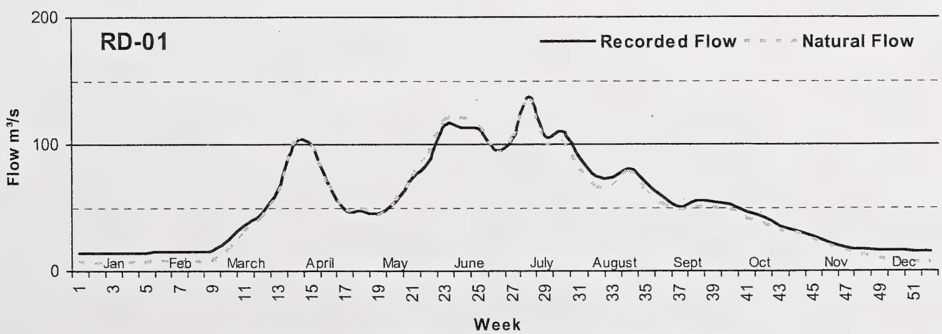
River: Red Deer River
Reach: No. 1
Consensus condition: Moderate Impact

Watershed Area (%): 2036.9 km^2 (12%)
Streams – linear (density): 1823.9 km (0.9)



Issues:

1. This reach includes the Red Deer River from the Bindloss gauging station to the Saskatchewan border (about 18 km from the confluence with the South Saskatchewan River).
2. Dickson Dam has had significant impacts on the two lowest reaches by reducing the highest flood peaks. Before the dam, the river had a shifting sand substrate. Since the dam, the river bed has stabilized and sand bars have become colonized by willows. There are also reductions in moderate to low flood peaks, which have resulted in a decrease in cottonwood recruitment.
3. Reduction in forest cover, which leads to less diversity in wildlife.
4. Extensive livestock operations (cow-calf operations), water extraction, grazing and wintering of cattle in riparian zones.
5. Oil and gas operations and pipeline crossings.
6. Key species include cottonwood, goldeye, walleye and sauger.
7. Exotics include Canada thistle and smooth brome grass.



Natural Flows (1983 - 1995) Recorded Flows (1983 - 1995)

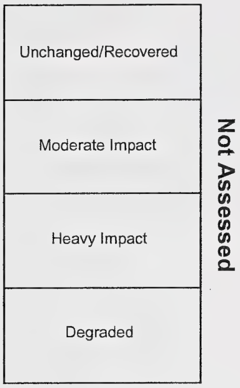
Knowledge Gaps Identified in the Red Deer River Assessment

1. Need monitoring of aging pipelines and consideration of increasing risk of toxic spills.
2. Require data on unlicensed water withdrawals in lower reaches.
3. Require data on wetland removal/drainage projects as too many wetlands have been drained (up to 80-90% in this area).
4. Develop an overall understanding of how land use affects the watershed including tributaries.
5. Better baseline data on the natural flow regime, especially for the tributaries.
6. The Dickson Dam has only been operating for 20 years, thus no long-term conclusions can be made regarding its impact and equilibrium conditions. This needs to be studied (part of this change is also a different winter flow/ice formation regime and its effects).
7. Quantifiable data on riparian health/conditions. Lack of stream gauging and water quality data on tributaries.
8. Require more thorough monitoring and assessment of fish community.
9. Temperature impact of return flows from irrigation is unknown. Require temperature data at existing flow monitoring stations.

River: Bow River
Reach: Headwaters
Consensus condition: n/a

Watershed Area (%): 7738.3 km^2 (31%)
Streams – linear (density): 8571.3 km (1.1)

Bow River - Headwaters

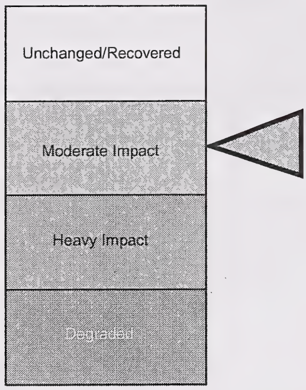


Issues:
1. The group of reaches above the Bearspaw Dam was not included in this assessment.
2. This section of river is highly altered with the Ghost, Seebe, and Horseshoe dams on the mainstem and the Upper and Lower Kananaskis, Spray Lakes, and Minnewanka reservoirs on tributaries.
3. These dams act as sediment and nutrient traps that result in relatively nutrient poor water flowing downstream.
4. Forestry is the major land use in this watershed.
5. The water quality in this region has not been adversely influenced to a significant extent by any major sources of contaminants and is considered to be of relatively high quality, although the growing communities of Lake Louise, Banff, and Canmore release municipal effluent. Little water is removed in these reaches although alteration of flow and habitat connectivity by hydroelectric facilities is an issue.

River: Bow River
Reach: No. 5
Consensus condition: Moderate Impact

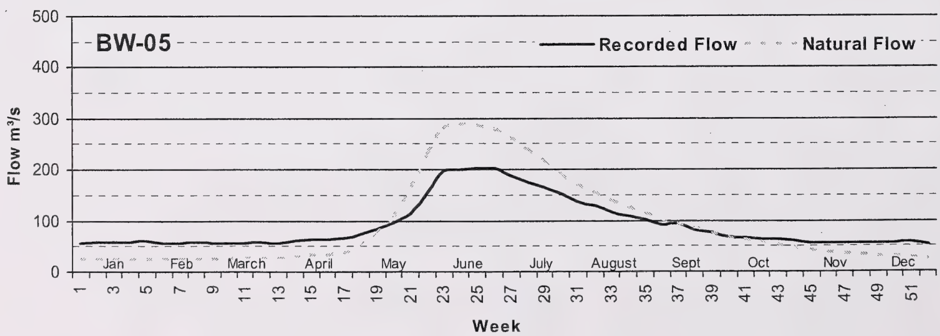
Watershed Area (%): 2368 km^2 (9%)
Streams – linear (density): 3055.7 km (1.3)

Bow River - Reach #5



Issues:

1. This reach includes the Bow River from Bearspaw Dam downstream through the north half of the City of Calgary to the WID Weir. The Elbow River and Glenmore Reservoir are within the watershed, as is Nose Creek. The Bearspaw Dam provides a stabilized flow to offset the upstream hydro-peaking and to provide a stable flow through Calgary. There are neither major industries nor major effluent outfalls within this reach. It does, however, receive stormwater runoff, and contains the former Canada Creosote site that once resulted in creosote seepage into the Bow River, which has since been contained.
2. Key flow issues include seasonal shift in flow regime, loss of high flows in small to medium flood events, enhanced winter flows, and potential changes to ice regime.
3. City 'footprint' increases peaks of storm events and stormwater runoff may degrade water quality.



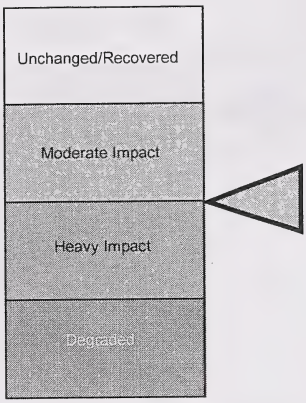
Natural Flows (1954 - 1995) Recorded Flows (1954 - 1995)

4. The water quality in this region is relatively good. Little water is removed in this or higher reaches with the exception of the City of Calgary withdrawals from Bearspaw and Glenmore reservoirs; wastewater return occurs in the next downstream reach of the Bow River. The re-regulation of hydropeaking flows is thought to be a benefit as are higher winter flows.
5. The floodplain is generally non-functional due to channelization and armored banks within city. Floodplain vegetation succession is limited by residential development and dominated by urban forestry (exotics). No age-class structure is obvious (*i.e.*, no natural recruitment, predominantly mature trees).
6. Land use includes urban development, gravel pits, golf courses. The watershed of the headwaters of the Elbow River includes the Sarcee Reserve, forest lands around Bragg Creek and acreage developments.
7. Key species in the river include mountain whitefish and brown and rainbow trout.
8. Exotic species comprise the riparian vegetation, but lack of expertise within the panel on terrestrial vegetation precluded detailed comment.

River: Bow River
Reach: No. 4
Consensus condition: Moderate to Heavy Impact

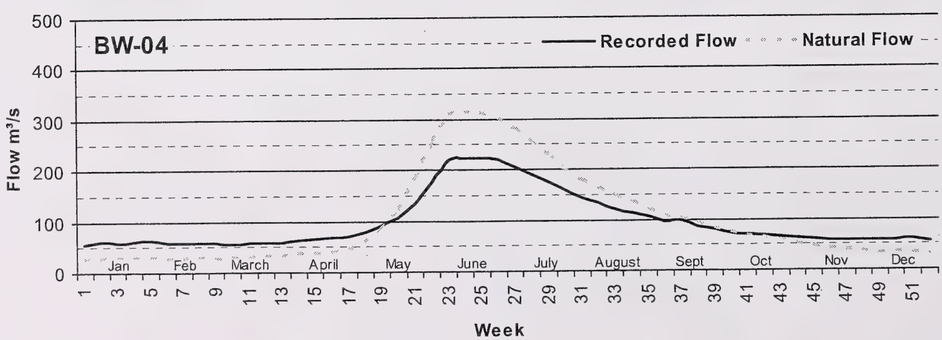
Watershed Area (%): 1139.2 km^2 (5%)
Streams – linear (density): 1110.5 km (1.0)

Bow River - Reach #4



Issues:

1. This reach includes the Bow River from the WID Weir to the confluence of the Highwood River. The influence of the stabilized flow from the Bearspaw Dam is still significant in this reach. This reach includes the southern half of the City of Calgary and includes the Bonnybrook and Fish Creek sewage outfalls as well as the major industrial parks.
2. Key flow issues include seasonal shift in flow regime, loss of high flows in small to medium flood events, and enhanced winter flows.
3. City 'footprint' increases peaks of storm events and stormwater run-off may be of poor quality.
4. The water quality in this region has improved due to upgrading of the sewage treatment in Calgary; the sewage outfalls provide an enriched environment in this and downstream reaches.

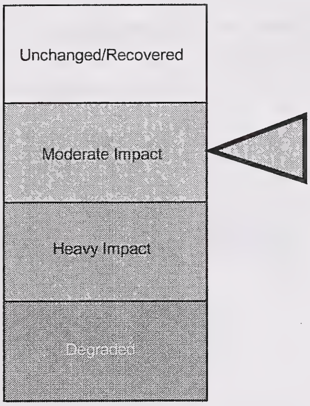


Natural Flows (1954 - 1995) Recorded Flows (1954 - 1995)

5. The first significant loss of water from the Bow River occurs at the WID Weir; this withdrawal only occurs during the summer irrigation season; the water flows through Lake Chestermere. Loss of fish to the irrigation outtake occurs.
6. The floodplain functions better than that in BW-05. The floodplain vegetation is in relatively good shape, although much (in the City of Calgary) is considered to be non-native.
7. Land use includes urban development, gravel pits, golf courses, limited ranching (cow-calf operations) and cultivated crops.
8. Key species in the river include mountain whitefish and brown and rainbow trout.
9. Exotic species comprise the riparian vegetation, but lack of expertise within the panel precluded detailed comment.

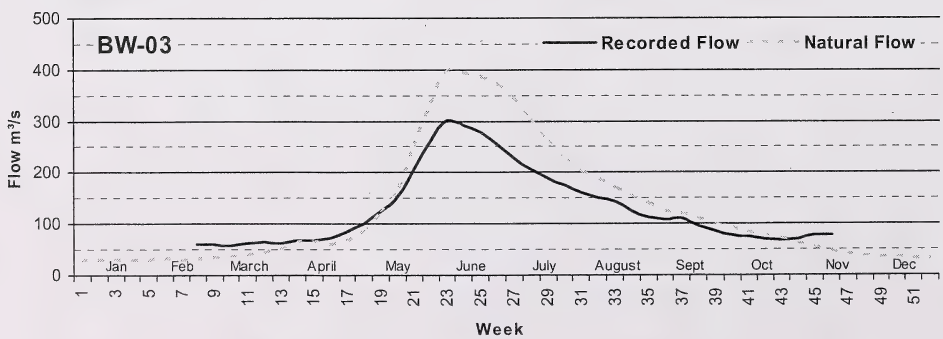
River: Bow River
Reach: No. 3
Consensus condition: Moderate Impact
Watershed Area (%): 4396.6 km^2 (17%)
Streams – linear (density): 7110.6 km (1.6)

Bow River - Reach #3



Issues:

1. This reach includes the Bow River from the confluence of the Highwood River to the Carseland Weir. The watershed includes the Highwood River which exerts a significant influence in this reach; the Highwood has no major impoundments and as a result has a 'natural flow' except for relatively small agricultural withdrawals throughout the watershed.
2. The Highwood River has a diversion that moves some water to the Little Bow River and on to the Oldman River system.
3. This reach exhibits some recovery towards a natural flow regime due to discharges from the Highwood River. The flows are somewhat enhanced due to downstream water conveyance for irrigation license priorities (oldest licenses) of the Bow River Irrigation District (BRID) and EID.
4. The water quality in this region has improved due to upgrading the (upstream) sewage treatment in Calgary and removal of High River's sewage from the Highwood River.

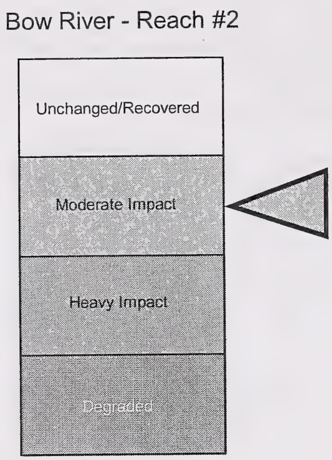


Natural Flows (1954 - 1995) Recorded Flows (1970 - 1995)

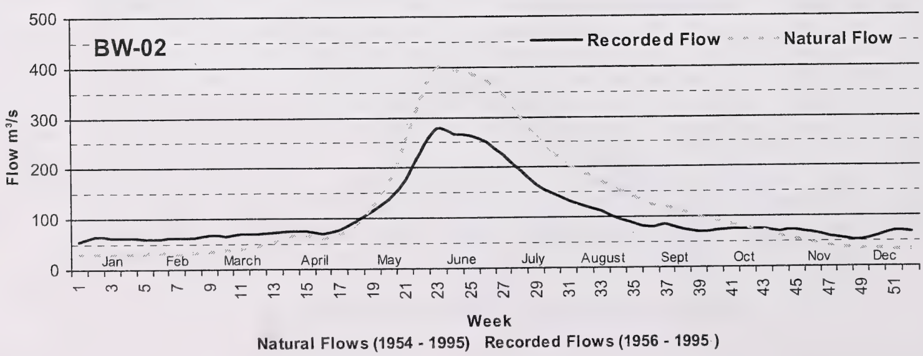
5. The sewage outfalls provide an enriched environment in this and downstream reaches. Coupled with the enhanced winter flows from Bearspaw Dam, this is thought to result in a highly productive sport fishery for non-native trout (rainbow and brown trout).
6. There is a small irrigation return flow containing some fertilizers and pesticides, but it is relatively insignificant considering the volume of the Bow River.
7. The floodplain has not been structurally altered and is only affected by the change in flow regime. Natural progression in riparian zone from prairie cottonwood to balsam poplar.
8. Land use includes agriculture and ranching (cow-calf operations).
9. Key species in the river include mountain whitefish, brown and rainbow trout.

River: Bow River
Reach: No. 2
Consensus condition: Moderate Impact

Watershed Area (%): 4294.5 km^2 (17%)
Streams – linear (density): 3800.8 km (0.9)



Issues:
1. This reach includes the Bow River from the Carseland Weir downstream to Bassano Dam. A small irrigation flow (from WID) is transferred to Eagle Lake in the northwest of the watershed. Trans-basin irrigation flows are transferred via McGregor Lake, south of the watershed, into the Oldman sub-basin, and to the north, to Crawling Valley Reservoir and into the Red Deer sub-basin.
2. This reach has a major extraction canal at its downstream limits (EID) and thus has much more water than the further downstream reach due to the license priority of the EID at Bassano Dam. Loss of fish to the irrigation outtake occurs.
3. Flows in this reach are relatively good due to the passage of water to the EID canal at the bottom of the reach.
4. Reduced peak flows and impoundments result in reduced sediment transport capability.
5. The water quality in this region has generally improved due to better wastewater treatment upstream and water conveyance to the EID outlet in the Bassano Dam.



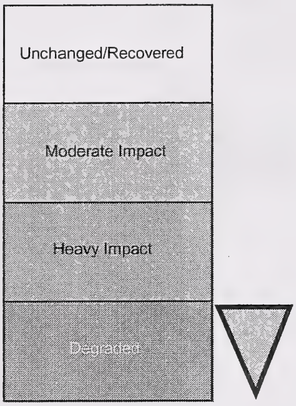
6. There are limited irrigation return flows transporting some fertilizers, pesticides, and nutrients from feedlots (*e.g.*, Crowfoot Creek), although impacts on water quality are relatively insignificant considering the flow of the Bow River in this reach.
7. The floodplain has not been structurally altered and is only affected by the change in flow regime. Natural progression in riparian zone from prairie cottonwood to balsam poplar.
8. Land use includes crops, ranching, and confined feeding operations (CFO[4]).
9. Key species in the riparian zone is the cottonwood; in the river includes mountain whitefish and brown trout.

[4] Previously referred to as intensive livestock operations (ILO).

River: Bow River
Reach: No. 1
Consensus condition: Degraded

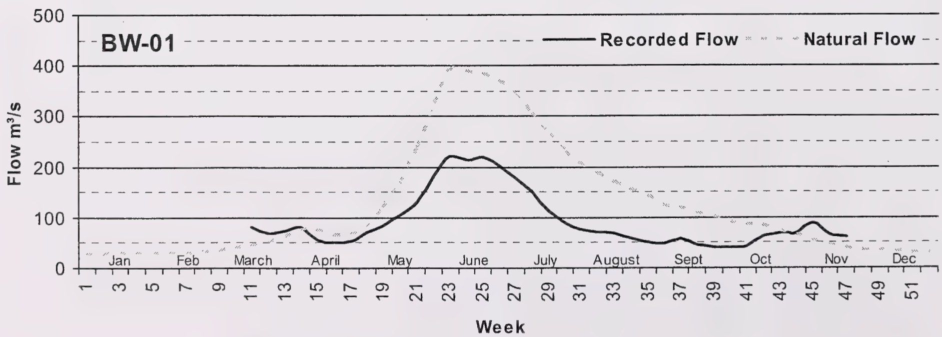
Watershed Area (%): 5229.3 km^2 (21%)
Streams – linear (density): 3297.9 km (0.6)

Bow River - Reach #1



Issues:

1. This reach includes the Bow River from the Bassano Dam downstream to the 'Grand Forks' at the confluence with the Oldman River. Irrigation flows are transferred to Lake Newell in the north centre of the watershed.
2. Flow in this reach is the lowest of any reach of the river and it is considered the most highly degraded reach of the Bow River sub-basin, with a declining trend.
3. Lowest average and monthly flows during the summer diversion period, and reduced flood events. The flow and water quality are considered the key themes that the BJP considered degraded, although the water quality has improved somewhat in recent years.
4. Reduced flows and impoundments have resulted in reduced sediment transport and increased temperatures.
5. There are limited irrigation return flows with some fertilizers, pesticides, and nutrients from feedlots.



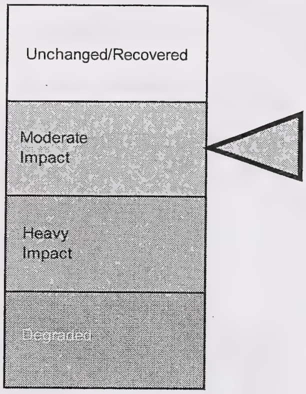
Natural Flows (1954 - 1995) Recorded Flows (1964 - 1995)

6. The floodplain has not been structurally altered but is greatly affected by the reduced flow. Silt and to some extent nutrients are trapped in the upstream Bassano Reservoir.
7. Land use includes crops, ranching, and CFOs.
8. Key species in the riparian zone is the cottonwood (seriously degraded state as most are dead with little or no signs of recruitment).

River: South Saskatchewan River
Reach: No. 2
Consensus condition: Moderate Impact

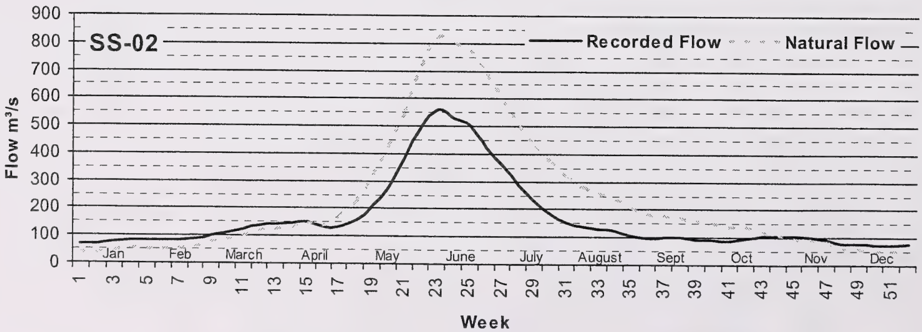
Watershed Area (%): 2630.6 km^2 (22%)
Streams – linear (density): 2074.8 km (0.8)

South Saskatchewan River - Reach #2



Issues:

1. This reach includes the South Saskatchewan River from the 'Grand Forks' of the Bow and Oldman rivers to the WSC gauge in Medicine Hat.
2. This reach experiences low summer flows during drought years as water is extracted upstream on both the Bow and Oldman rivers.
3. Although there have been no IFN assessments on the South Saskatchewan River to develop environmental flows, management has been trying to maintain 50 m^3/s flow by supplementing the flow with water from the Oldman Reservoir.
4. Reduced flood regime has an impact on riparian and riverine zones.
5. Medicine Hat footprint and its affects on stormwater runoff, quality and quantity (sewage, pesticides, fertilizers, etc.).
6. Land use includes crops, ranching, and CFOs. There are some problems with winter grazing in riparian zones and effects on native vegetation.
7. Key species in the river are sauger, walleye, northern pike, and some lake sturgeon (vulnerable status).
8. Key species in the riparian zone is the prairie cottonwood (somewhat degraded state).

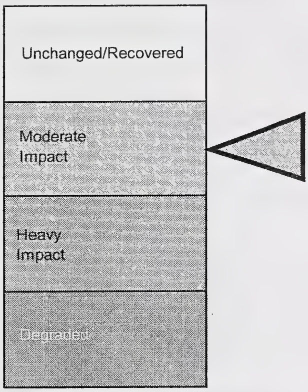


Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

River: South Saskatchewan River
Reach: No. 1
Consensus condition: Moderate Impact

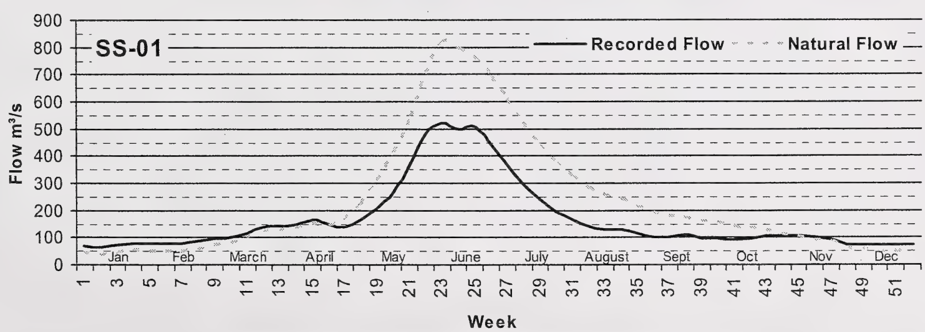
Watershed Area (%): 9517.7 km^2 (78%)
Streams – linear (density): 9016.1 km (1.0)

South Saskatchewan River - Reach #1



Issues:

1. This reach includes the South Saskatchewan River from the WSC gauge in Medicine Hat to the Alberta/Saskatchewan border.
2. This reach experiences low summer flows during drought years as water is extracted upstream on both the Bow and Oldman rivers.
3. The reduced flood regime has had an impact on riparian and riverine zones.
4. Substantial oil and gas effects including water extraction below Medicine Hat and a lack of successful restoration work on pipeline watercrossings.
5. Medicine Hat footprint and its affects on storm water runoff, quality and quantity (sewage, pesticides, fertilizers, etc.).
6. Land use includes crops, ranching, and CFOs. There are some problems with winter grazing in riparian zones and effects on native vegetation.
7. Key species in the river include sauger, walleye, northern pike, and lake sturgeon (vulnerable status).
8. Key species in the riparian zone is the cottonwood (serious impacts from grazing and reduced flooding).



Natural Flows (1966 - 1995) Recorded Flows (1966 - 1993)

Knowledge Gaps Identified in Bow and South Saskatchewan Rivers Assessment

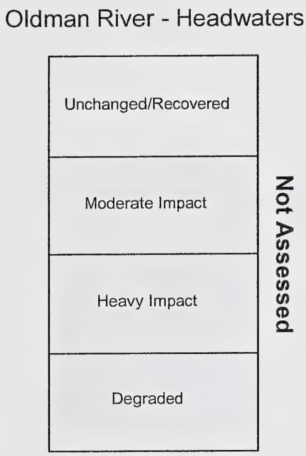
The Bow River and its major tributary, the Highwood, have had IFN assessments and studies (IEC Beak 1985, Englert *et al.* 1987, EMA 1994, Rood *et al.* 1999) conducted to determine the environmental flows for the various reaches. This work has been insufficient to fully understand the complex impacts that changing the flow regime in both quantity and timing has had on the Bow River sub-basin ecosystem. The BJP identified several key gaps in our understanding that will hamper the future ability of the management team to make the most effective decisions regarding water use. These include:

1. The impact of climate change on both water availability and demand throughout the sub-basin and southern Alberta.
2. Hydrologic flow/flood duration, particularly in winter.
3. A working water quality model would assist in interpreting the effects of reduced water flows.
4. Require more riparian vegetation data on most of the river, particularly the state of the cottonwoods in BW-02 and BW-01. The reaches of the South Saskatchewan River have limited data available for riparian vegetation status; in addition, it will be necessary to monitor the major pipeline crossing sites to assess recovery and also the risk of a major hydrocarbon spill as the pipelines age.
5. Agricultural operations and licensed but un-recorded water withdrawal data on tributaries and the cumulative impacts of these activities on the watershed.
6. Data on the hyporheic[5] zone and effects of reduced flow on sediment transport and deposition.
7. Studies on chemicals, including pharmaceuticals (antibiotics and hormones), and their transport in both surface and groundwater.
8. Water temperature: enhanced data collection and modelling are required and a program has been proposed.
9. Sediment bedload movement and sediment and nutrient removal by impoundments throughout the sub-basin.
10. Fish inventories on all reaches need to updated and kept up to date. Studies on forage fish and mountain whitefish are required. Limited historical studies are available. South Saskatchewan River fish movement studies are old (>10 yrs), on-going studies are necessary to be able to assess the effects of flow diversions. The lake sturgeon has been identified as a species of concern (vulnerable status) with a high international profile.
11. Flood pulsing effects, including the range of spring freshets, are not well understood in relation to fish populations and aquatic life, and the implications for the food chain.
12. A literature review of historic status of species, range of flows, etc. is required.
13. Studies on the risk of exotics, such as New Zealand mud snails, clams, Eurasian milfoil, etc. are required. Monitoring could be conducted at boat launch sites.
14. Sub-basin (Bow & South Saskatchewan) land-use studies (mostly agriculture) are required to make the baseline dataset comparable with those of the Oldman sub-basin.
15. South Saskatchewan River requires water quality monitoring and studies particularly as related to waste water from Medicine Hat.

[5] Hyporheic zone is the region of the river bed that allows active transport of water through the sediments, important for fish spawning for nest builders and nutrient supply to rooted macrophytes.

River: Oldman River
Reach: Headwaters
Consensus condition: n/a

Watershed Area (%): 1441.9 km^2 (7%)
Streams – linear (density): 3334.9 km (1.1)



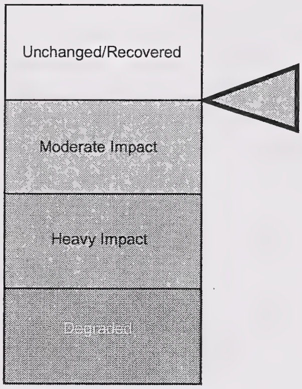
Issues:

1. The group of reaches above Waldron's Corner (near bridge on Hwy 22) was not included in this assessment.
2. This section of river has limited impact from forestry above 'the Gap' and ranching between 'the Gap' and Hwy 22. Major impacts are probably due to access roads and linear corridors.
3. The water quality in this region is good as it has not been influenced by any major sources of contaminants. Little water is removed in these reaches, although some local allocations have been made.

River: Oldman River
Reach: No. 8
Consensus condition: Unchanged to Moderate Impact

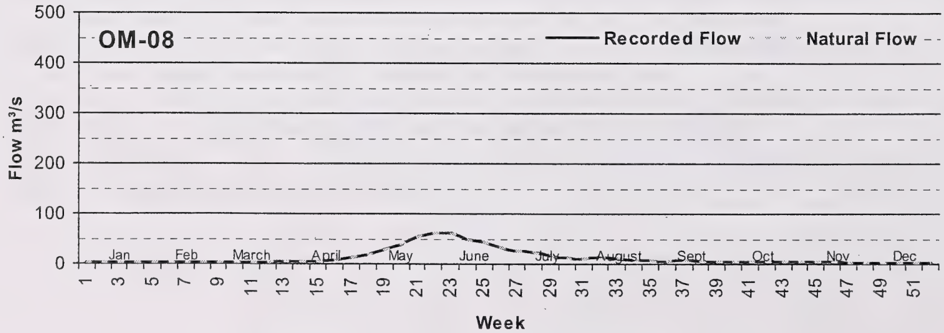
Watershed Area (%): 2932.5 km^2 (14%)
Streams – linear (density): 5381.4 km (1.8)

Oldman River - Reach #8



Issues:

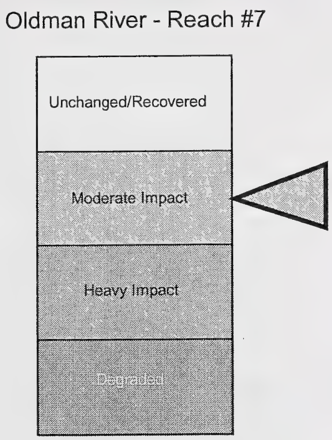
1. This reach includes the Oldman River from Waldron's Corner downstream to the Oldman Dam. The Castle and the Crowsnest rivers are the two main tributaries within the watershed. The dam provides a reserve capacity and stabilized flow to offset the downstream extraction for agriculture. There are neither major industries nor effluent outfalls within this reach, although there has been a long history of coal mining within the watershed.
2. Forestry and road development are major influences in the form of linear corridors.
3. Grazing leases, limited irrigation, oil and gas, recreation and municipal uses all exert minor effects.
4. The dam isolates this reach from the downstream OM-07.
5. Key species identified as bull trout.
6. Exotics include Canada thistle, smooth brome grass and Kentucky bluegrass.



Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

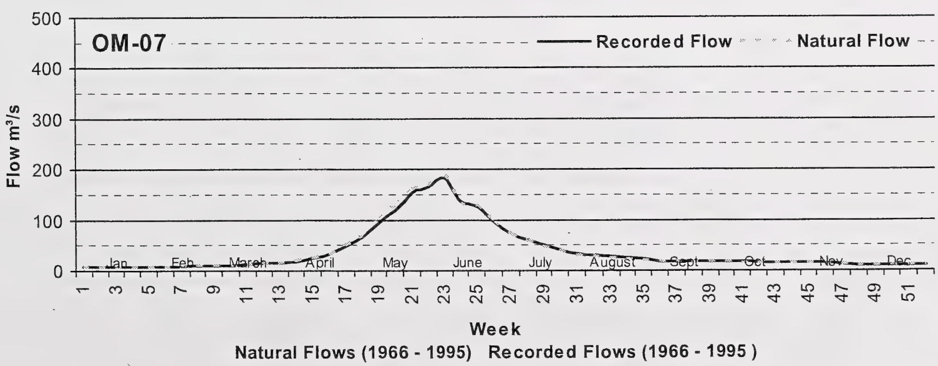
River: Oldman River
Reach: No. 7
Consensus condition: Moderate Impact

Watershed Area (%): 35 km^2 (0.2%)
Streams – linear (density): 46.9 km (1.3)



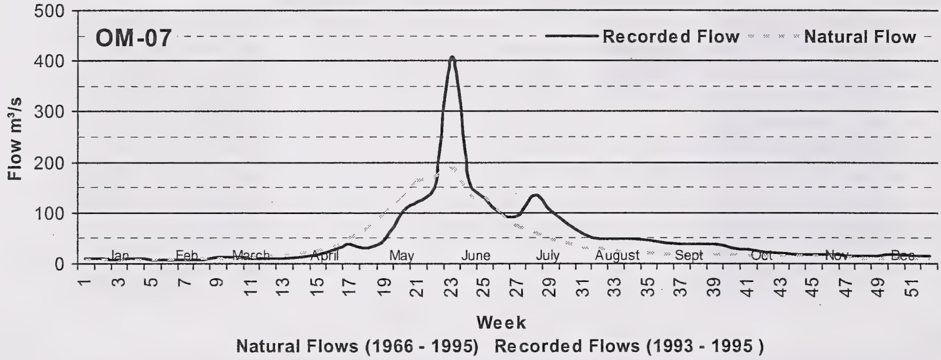
Issues:

1. This reach includes the Oldman River from the Oldman Dam downstream to the confluence of Pincher Creek and the Oldman River. The watershed for OM-07 is small.
2. The dam is causing impact by alteration of water temperature through delayed spring warming and winter cooling, acting as a sediment sink releasing nutrient poor water, and blocking fish movement.
3. Water temperatures colder in the summer, warmer in the winter due to bottom release from reservoir. This has led to a change in the benthic community downstream of the damsite.
4. Loss of spring high flood flows combined with higher stabilized winter flows has reduced the natural mortality of attached (epilithic) algae resulting in an atypical accumulation.
5. Reduced sediment bedload leads to a decrease in flood plain aggregation/development with implications for bank erosion, especially immediately downstream.



Note: The hydrograph for OM-07 covers the period 1966 - 1995. The most recent period, since 1992, would show a different curve due to the installation of the Oldman Dam. See hydrograph on following page.

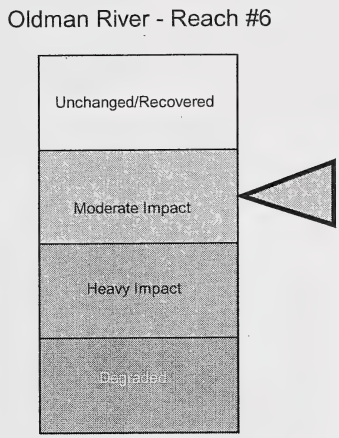
6. Loss of peak flood flows is affecting riparian vegetation, most notably decreased cottonwood recruitment.
7. Declines in number and distribution of bull trout.
8. Key species identified as brown and rainbow trout.
9. Exotics include smooth brome, Kentucky bluegrass, Canada thistle, leafy spurge and Russian olive.



Note: This hydrograph for OM-07 shows the recorded flow for the period 1993 to 1995. The time period shows the flow curve after the closure of the Oldman Dam. In 1995, a large flood, considered the flood of the century, resulted in a peak that will distort the 'average' flow for many years. The change in seasonal flow distribution due to the dam would apply to all downstream reaches of the sub-basin; its effect becomes less pronounced in the downstream reaches.

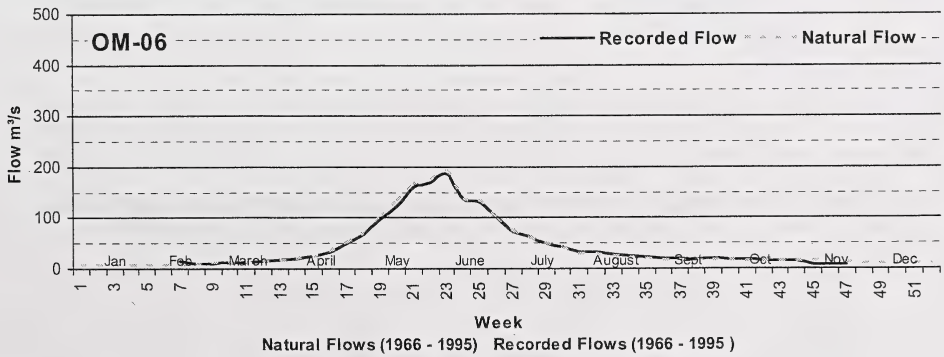
River: Oldman River
Reach: No. 6
Consensus condition: Moderate Impact

Watershed Area (%): 1166.2 km^2 (6%)
Streams – linear (density): 1799.8 km (1.5)



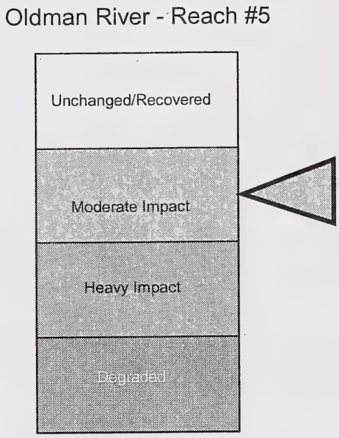
Issues:

1. This reach includes the Oldman River downstream from the confluence of Pincher Creek and the Oldman River to the Lethbridge Northern Irrigation District (LNID) Weir. Pincher Creek is the only significant tributary within this reach. The only major point source of effluent within this reach is the Town of Pincher Creek.
2. Loss of spring high flows for flushing sediments, removing macrophytes, and epilithic algae. Loss of peak floods has reduced regeneration of riparian vegetation.
3. There are some concerns with bank erosion downstream of the dam.
4. No major sources of water loss in this reach or upstream. The dam does not significantly affect seasonality of flows, some possible improvements in fish habitat due to increase in minimum winter flows. Water temperatures colder in the summer, warmer in the winter due to bottom release from reservoir.
5. Bull trout spawning and migration blocked by the dam.
6. Key species include brown and rainbow trout and cottonwoods.
7. Exotics include Russian olive, Kentucky bluegrass, and leafy spurge.



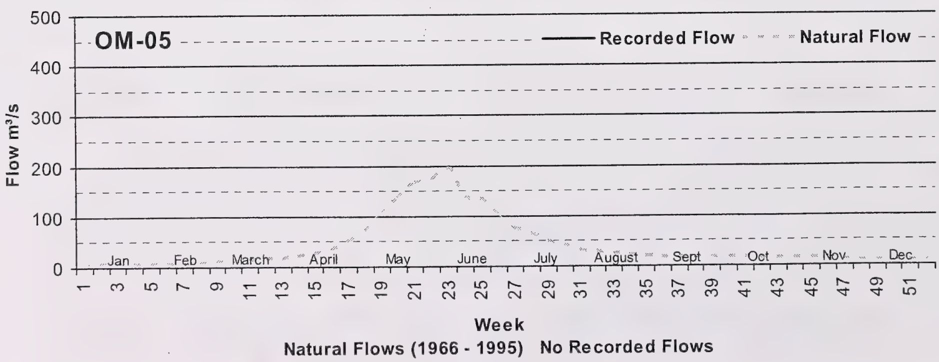
River: Oldman River
Reach: No. 5
Consensus condition: Moderate Impact

Watershed Area (%): 344.2 km^2 (2%)
Streams – linear (density): 216.9 km (0.6)



Issues:

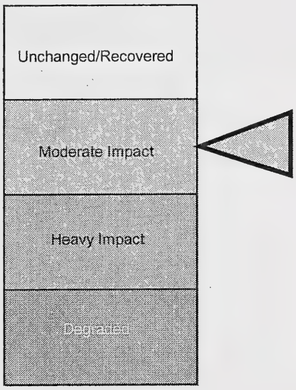
1. This reach includes the Oldman River downstream from the LNID weir to the Willow Creek confluence.
2. Water temperature is colder in the summer, warmer in the winter due to bottom release from reservoir.
3. The first major water abstraction in the Oldman River occurs at the LNID Weir. Loss of fish to the irrigation outtake occurs.
4. Loss of spring high flows for flushing sediments and removing macrophytes.
5. There may be some improvement in water quality due to a year-round increase in minimum flows as a result of creation of the Oldman Reservoir.
6. Little regeneration of woody vegetation (cottonwoods) in riparian zone(s).
7. Key species include brown and rainbow trout and cottonwoods.
8. Exotics include Russian olive, Kentucky bluegrass, and leafy spurge.



River: Oldman River
Reach: No. 4
Consensus condition: Moderate Impact

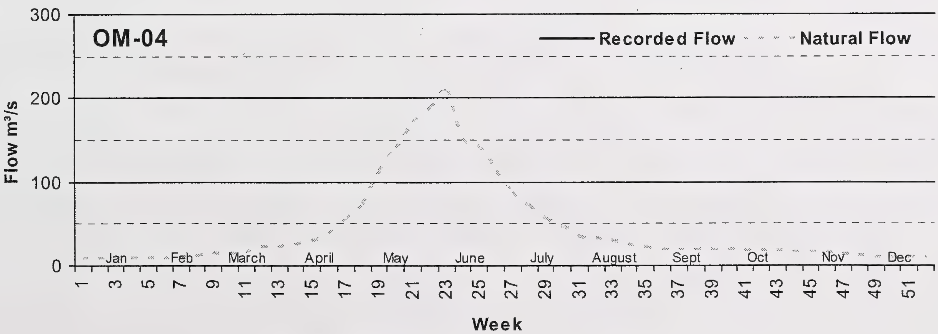
Watershed Area (%): 3309.8 km^2 (16%)
Streams – linear (density): 4510.5 km (1.4)

Oldman River - Reach #4



Issues:

1. This reach includes the Oldman River downstream from the confluence with Willow Creek to the confluence of the Belly River with the Oldman River. Mud Lake, an large internal drainage slough, and Chain Lakes Reservoir (located on Willow Creek) are located within this watershed. (The Belly River and its tributary, the Waterton River, although an integral part of the Oldman sub-basin have historically been managed as a separate sub-system referred to as part of the southern tributaries).
2. Reduction of low and medium flood peaks.
3. Reduction in sediment and bedload transport.
4. Loss of spring high flows for flushing sediments and removing macrophytes. There may be some improvement in water quality due to an increase in minimum flows as a result of creation of the Oldman Reservoir.

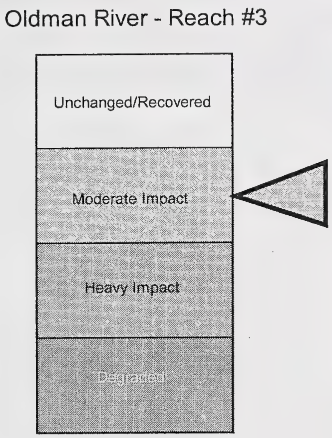


Natural Flows (1966 - 1995) No Recorded Flows

5. Little regeneration of woody vegetation (cottonwoods) in riparian zone(s).
6. Riparian zones often used as wintering sites for cow/calf operations.
7. Key species include brown and rainbow trout and cottonwoods.
8. Exotics include Russian olive, Kentucky bluegrass, and leafy spurge.

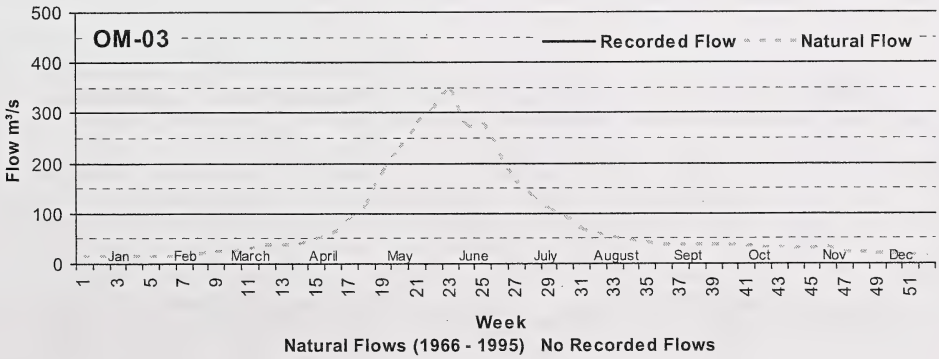
River: Oldman River
Reach: No. 3
Consensus condition: Moderate Impact

Watershed Area (%): 381.7 km^2 (2%)
Streams – linear (density): 319.0 km (0.8)

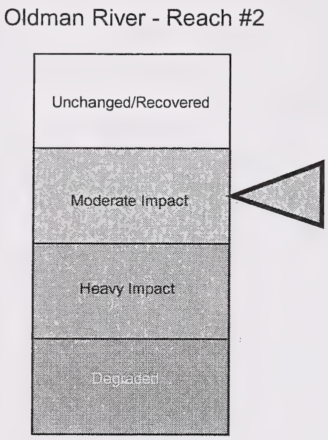


Issues:

1. This reach includes the Oldman River downstream from the confluence of the Belly River to confluence of the St. Mary River with the Oldman River. (The St. Mary River and its watershed, although an integral part of the Oldman sub-basin have historically been managed as a separate sub-system referred to as part of the southern tributaries).
2. Water abstraction from the Belly/Waterton system has resulted in less discharge to the Oldman River.
3. Loss of spring high flows for flushing sediments and removal of macrophytes is a concern. There is some improvement in water quality due to increases in minimum flows.
4. Intensive agriculture, irrigation, cattle grazing, and CFOs.
5. Little regeneration of woody vegetation (cottonwoods) in riparian zone(s).
6. Key species include brown and rainbow trout and cottonwoods.
7. Exotics include Russian olive, Kentucky bluegrass, and leafy spurge.

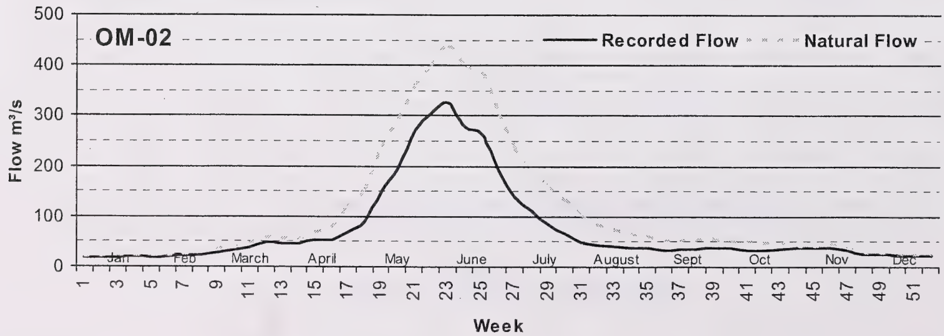


River: Oldman River
Reach: No. 2
Consensus condition: Moderate Impact
Watershed Area (%): 827.8 km^2 (4%)
Streams – linear (density): 823.5 km (1.0)



Issues:

1. This reach includes the Oldman River downstream of the St. Mary River confluence to the confluence with the Little Bow River. Keho Lake is located within this watershed.
2. Water abstraction from the St. Mary River has resulted in a loss of discharge to the Oldman River.
3. There are a number of diversions/impoundments upstream of the bottom two reaches, that impact overall habitat connectivity of the river.
4. Weir at Lethbridge has been modified to allow fish passage; its effectiveness has not been evaluated.
5. Loss of spring high flows for flushing sediments and removing macrophytes.
6. The City of Lethbridge is the greatest single source of impact on Oldman River water quality.
7. The uptake of water by the City of Lethbridge and its return as treated waste effluent supplemented by stormwater have made water quality an issue in the lower two reaches; recent upgrades to the municipal wastewater treatment plant have led to an improvement in water quality.

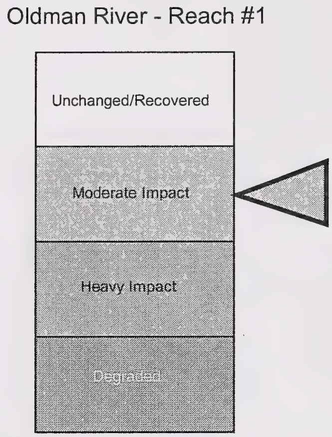


Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

8. Gravel mining impacts the floodplain in the lower reaches.
9. Intensive agriculture, irrigation, cattle grazing, and CFOs.
10. Riparian zones often used as wintering sites for cow/calf operations.
11. Little regeneration of woody vegetation (cottonwoods) in riparian zone(s) due to reduced spring flooding.
12. Key species include walleye, sauger, and lake sturgeon (vulnerable status) in the riverine areas and cottonwoods in the riparian zone.
13. Exotics include Russian olive, Kentucky bluegrass, and leafy spurge.

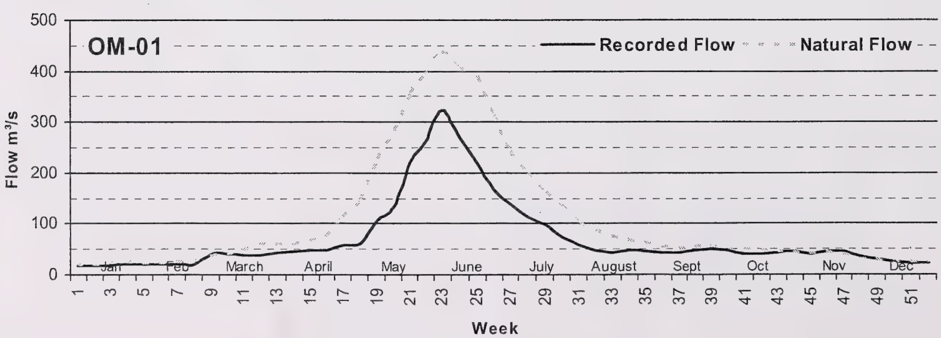
River: Oldman River
Reach: No. 1
Consensus condition: Moderate Impact

Watershed Area (%): 10241.9 km^2 (23%)
Streams – linear (density): 6287.1 km (0.6)



Issues:

1. This reach includes the Oldman River from the confluence of the Little Bow River to the South Saskatchewan. Travers Reservoir (integrated with McGregor Lake) is located within this watershed (water is transferred via the Little Bow River from the Highwood River of the Bow River sub-basin to the Oldman sub-basin).
2. Loss of spring high flows for flushing sediments and removing macrophytes; little regeneration of riparian vegetation (cottonwoods).
3. Treated waste effluent augmented by stormwater from the City of Lethbridge has made water quality an issue in the lower two reaches; recent upgrades to the municipal wastewater treatment plant have led to an improvement in water quality.
4. Gravel mining impacts the flood plain in the lower reaches.
5. Intensive agriculture, irrigation, cattle grazing, and CFOs. Riparian zones often used as wintering sites for cow/calf operations.
6. Key species include walleye, sauger, lake sturgeon (vulnerable status), and cottonwoods.
7. Exotics include Russian olive, Kentucky bluegrass, and leafy spurge.



Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

Knowledge Gaps Identified in Oldman River Assessment

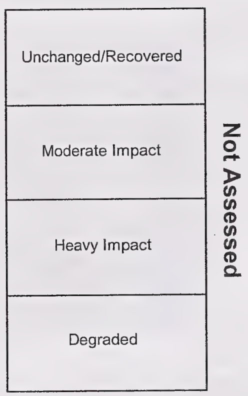
1. Forest harvesting and access road development effects on sediment loading in rivers. In particular, the impacts should be studied after a large flood event in the higher reaches (OM-08 and the headwaters).
2. There is a need to review information and state more specific information on agricultural impacts in the higher reaches.
3. The weir at Lethbridge has been improved for fish movement, but there is no data on its effectiveness.
4. Studies on naturalized flows vs. regulated flows have been done; it is necessary to gain data for a more extended time series with the Oldman Dam.
5. Require more flow monitoring stations on smaller tributaries. The current focus has been on the mainstem but it is also necessary to assess the cumulative effects on the tributaries. Tributary stream assessments need to be conducted. Without these data, it will be difficult to follow a "watershed" approach to this management initiative.
6. Stream classification needs to be completed (GIS work is underway).
7. River regime studies should include:
   a. flow regime changes;
   b. sediment transport effects; and,
   c. channel morphology effects.
8. A working water quality model is needed for the Oldman River.
9. A study has been initiated on cottonwood hybridization, but needs to be continued.
10. Studies on the effects of climate change.
11. Benthic invertebrate monitoring, studies, and reporting downstream of the dam.
12. Studies on non-point source input of nutrients in the river system (water quality monitoring).
13. Surveys of wintering populations of deer, other mammals and birds, and general riparian 'health'.
14. Historical assessment of riparian information should be reviewed from "Dawson's reports" (written in the 1800s).
15. A geomorphic assessment of the Oldman sub-basin comparable to that available for the Bow needs to be completed.
16. Monitoring for presence of exotic biota for early detection.
17. Develop a detailed list of the instream flow water rights compared to the actual extraction and water use.

The Southern Tributaries of the Oldman River Sub-basin

River: St. Mary River
Reach: Headwaters
Consensus condition: n/a

Watershed Area (%): 500.1 km^2 (9%)
Streams – linear (density): 713.9 km (1.4)

St. Mary River - Headwaters

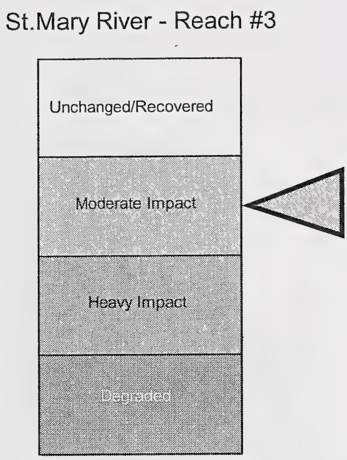


Issues:

1. The group of reaches above Woolford Provincial Park was not included in this assessment.
2. The upper St. Mary River flows through Montana from the Rocky Mountains starting in Glacier National Park; the 1909 Boundary Waters Treaty allows American users to withdraw 25% of the first 18.9 m^3/s and 50% of the remaining flow during the irrigation season (April through October) and 50% of the flow during the rest of the year.
3. This section of river is heavily used for agriculture including irrigation.
4. The water quality monitoring data in this watershed (except for SM-01) is more than 10 years old.

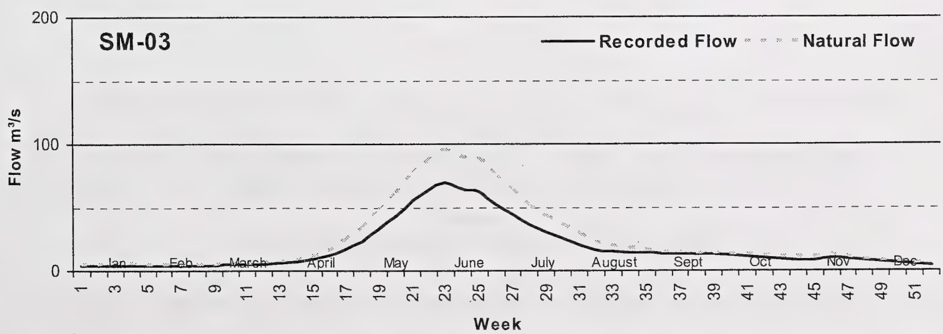
River: St. Mary River
Reach: No. 3
Consensus condition: Moderate Impact

Watershed Area (%): 519.6 km^2 (9%)
Streams – linear (density): 781.7 km (1.5)



Issues:

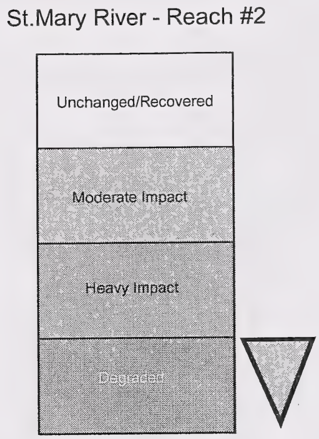
1. This reach includes the St. Mary River downstream from Woolford Provincial Park to the St. Mary Dam.
2. A major source of water comes from the Belly-Waterton system via canal to the St. Mary Reservoir.
3. Low flow throughout most of the year, flood controls and water extraction on all US tributaries reduce competent flows. These diversions in Montana affect fish distribution and composition.
4. Local irrigation diversions remove some water.
5. Bull trout spawning occurs in some higher reaches. St. Mary Reservoir provides a deep refuge pool for bull trout.
6. There is a shift from coldwater fish species to coolwater fish species in this reach.
7. Key species identified as cottonwoods and bull trout in the upper reaches.
8. Exotics identified as leafy spurge and alfalfa.



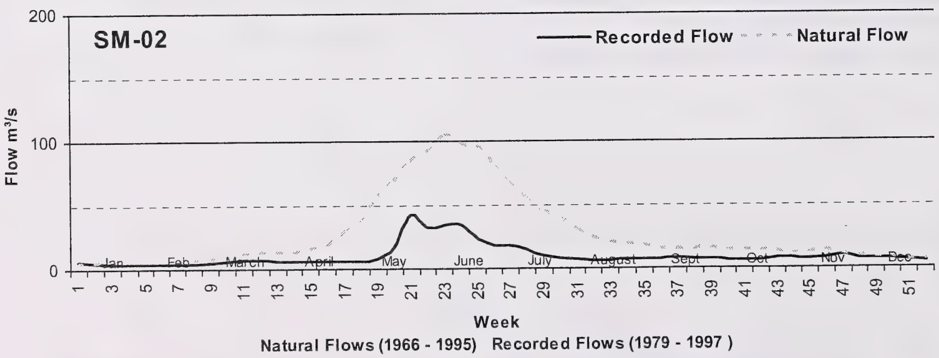
Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

River: St. Mary River
Reach: No. 2
Consensus condition: Degraded

Watershed Area (%): 346.6 km^2 (6%)
Streams – linear (density): 618.5 km (1.8)



Issues:
1. This reach includes the St. Mary River downstream of the St. Mary Dam to a point 37 km upstream of the confluence with the Oldman River.
2. Sediment captured in the reservoir has established a new equilibrium resulting in inadequate sediment transport to maintain downstream channel processes.
3. Riparian areas used as wintering sites for cattle; non-point runoff from agricultural activities.
4. Irrigation diversions.
5. Cottonwoods are dead this reach with no visible recruitment.
6. Key species identified as cottonwoods, walleye, and rainbow trout.
7. Exotics identified as leafy spurge and alfalfa.

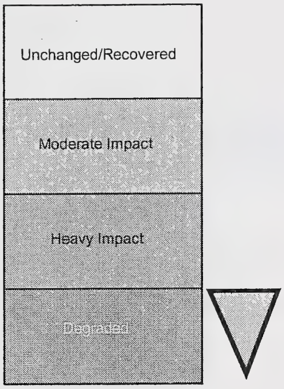


Note: The recorded flows taken from gauge GSTDAM and includes all the St. Mary Dam outflows.

River: St. Mary River
Reach: No. 1
Consensus condition: Degraded

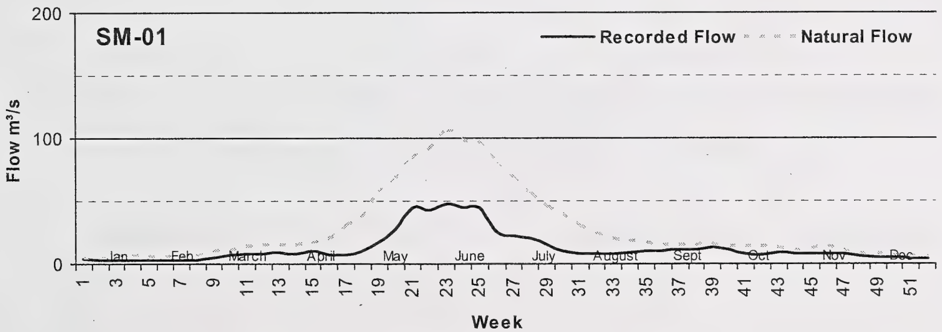
Watershed Area (%): 1070.7 km^2 (19%)
Streams – linear (density): 1518.7 km (1.4)

St.Mary River - Reach #1



Issues:

1. This reach includes the St. Mary River downstream from a point 37 km upstream of the confluence with the Oldman River to the Oldman River.
2. Low flow throughout most of the year.
3. Pothole Creek 'return flow' may adversely influence St. Mary River water quality.
4. Cottonwoods are dead this reach with no visible recruitment.
5. Key species identified as cottonwoods and walleye and rainbow trout.
6. Exotics identified as leafy spurge, and alfalfa.

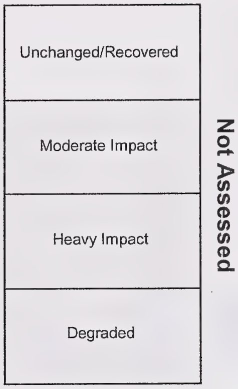


Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

River: Belly River
Reach: Headwaters
Consensus condition: n/a

Watershed Area (%): 247.3 km^2 (4%)
Streams – linear (density): 416.2 km (1.7)

Belly River - Headwaters



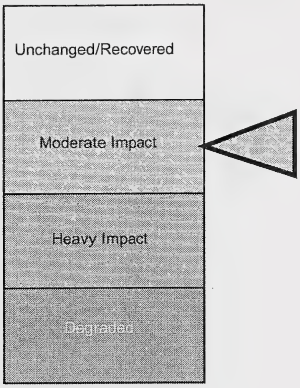
Issues:

1. The group of reaches above the confluence of Mami Creek was not included in this assessment. Payne Lake is included in this watershed.
2. This section of river is used for some agriculture and some forestry.
3. United Irrigation District (UID) Canal immediately upstream of BL-04 removes water and causes fish losses down the canal.
4. The water quality monitoring data in this watershed (except for BL-01) are more than 10 years old.
5. Key species identified as cottonwoods and bull trout in the upper reaches.

River: Belly River
Reach: No. 4
Consensus condition: Moderate Impact

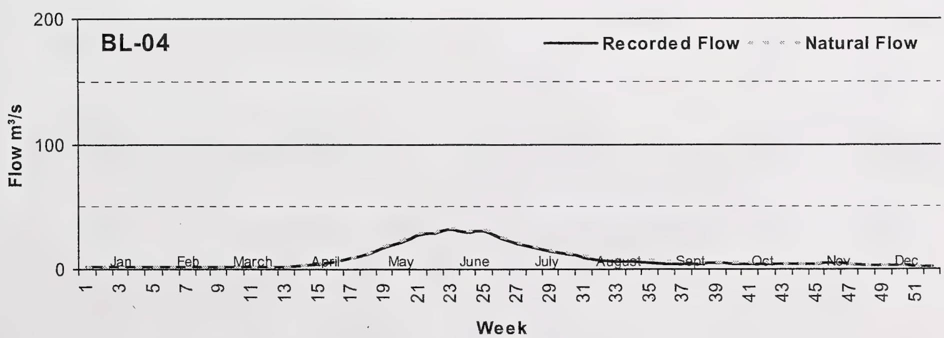
Watershed Area (%): 121.5 km^2 (2%)
Streams – linear (density): 205.8 km (1.7)

Belly River - Reach #4



Issues:

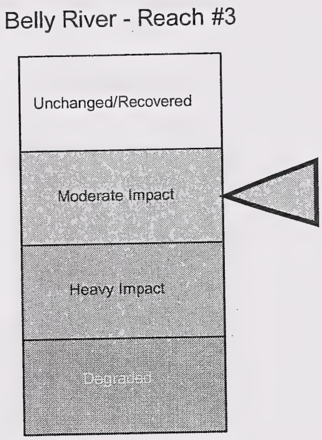
1. This reach includes the Belly River downstream from the Mami Creek confluence (near Hwy 800) to the St. Mary Canal (not including the canal).
2. Two diversions exist upstream of BL-04 (UID and Mountain View Irrigation District (MVID)); these are the first Canadian water withdrawals. The riparian health appears sustained in this reach and is not obviously impacted by the decreased flow.
3. Low flows resulting from diversions and extractions result in a shift from coldwater fish species to coolwater fish species.
4. High temperatures in summer can be limiting for trout species; bull trout are occasionally seen in this reach.
5. Riparian areas used as cattle wintering sites, resulting in non-point runoff from agricultural activities.
6. Gas bubble disease (gas supersaturation) may be an issue at the Belly Chute.
7. Key species in all reaches includes cottonwoods, which are healthy and have adequate recruitment. The key fish species in the upper reaches is bull trout.
8. Exotics identified as leafy spurge, Kentucky bluegrass, and Canada thistle.



Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

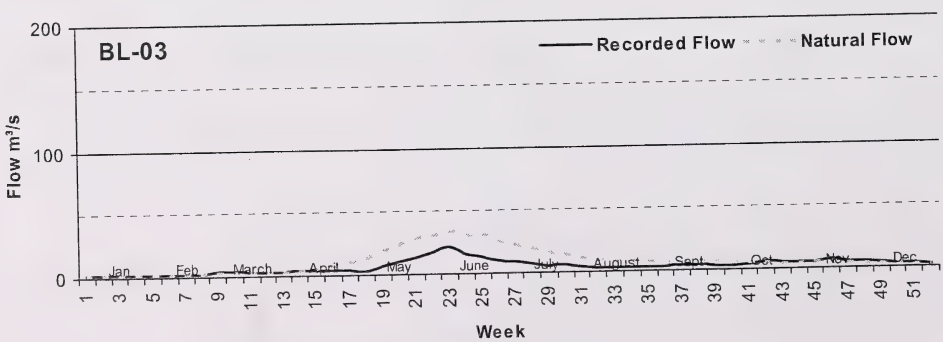
River: Belly River
Reach: No. 3
Consensus condition: Moderate Impact

Watershed Area (%): 36.1 km^2 (1%)
Streams – linear (density): 86.0 km (2.4)



Issues:

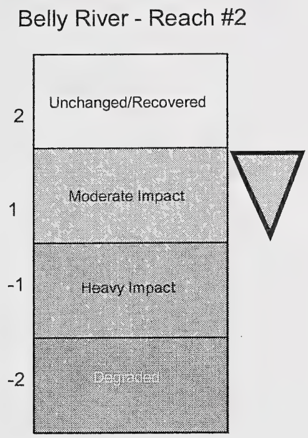
1. This reach includes the Belly River downstream of the St. Mary Canal (including the canal) to 125 km upstream of the confluence with the Oldman River.
2. Water is sent from the Belly/Waterton system via this canal to the St. Mary Reservoir to the east.
3. Low flow throughout most of the year. These diversions affect fish distribution and composition.
4. Low flows resulting from diversions and extractions have resulted in a shift from coldwater fish species to coolwater fish species.
5. High summer temperatures are limiting for trout species; bull trout are occasionally seen in this reach.
6. Riparian areas used as cattle wintering sites, resulting in non-point runoff from agricultural activities.
7. Key species in all reaches includes cottonwoods, which are healthy and have adequate recruitment. Key fish species include rainbow trout and mountain whitefish.
8. Exotics identified as leafy spurge, Kentucky bluegrass, and Canada thistle.



Natural Flows (1966 - 1995) Recorded Flows (1985 - 1995)

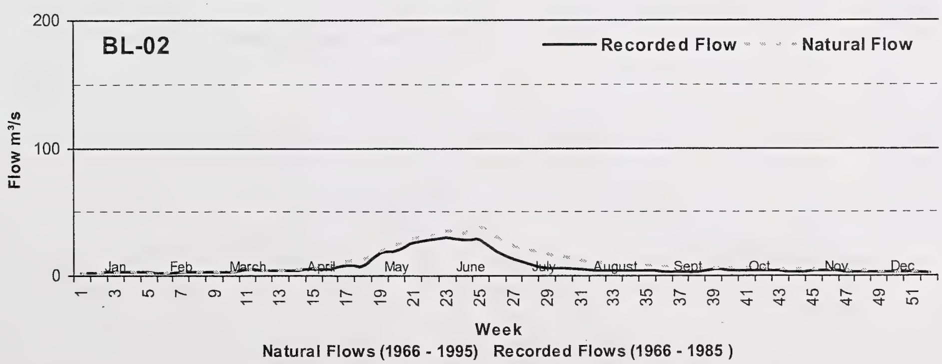
River: Belly River
Reach: No. 2
Consensus condition: Moderate Impact

Watershed Area (%): 653.1 km^2 (12%)
Streams – linear (density): 1319.3 km (2.0)



Issues:

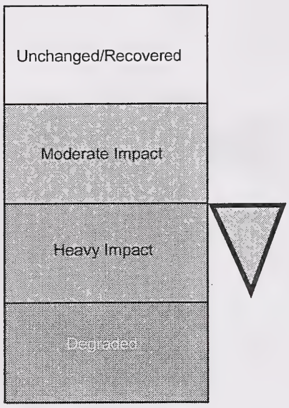
1. This reach includes the Belly River from 125 km upstream of the confluence with the Oldman River to the confluence with the Waterton River.
2. Low flow throughout most of the year. Upstream diversions affect fish distribution and composition.
3. Low flows resulting from diversions and extractions result in a shift from coldwater fish species to coolwater fish species.
4. Riparian areas used as wintering sites for cattle, resulting in non-point runoff from agricultural activities.
5. Key species in all reaches includes cottonwoods, rainbow trout, and mountain whitefish.
6. Exotics identified as leafy spurge, Kentucky bluegrass, and Canada thistle.



River: Belly River
Reach: No. 1
Consensus condition: Heavy Impact

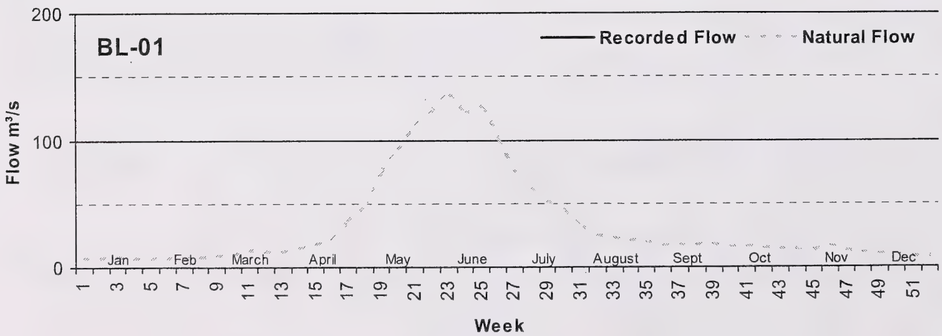
Watershed Area (%): 659.6 km^2 (12%)
Streams – linear (density): 655.7 km (1.0)

Belly River - Reach #1



Issues:

1. This reach includes the Belly River from the confluence with the Waterton River to the confluence with the Oldman River.
2. Low flow throughout most of the year. The upstream diversions affect fish distribution and composition.
3. Reduced flood peaks.
4. Riparian areas used as wintering sites for cattle, resulting in non-point runoff from agricultural activities.
5. Key species in all reaches includes cottonwoods, rainbow trout, and mountain whitefish.
6. Exotics identified as leafy spurge, Kentucky bluegrass, and Canada thistle.

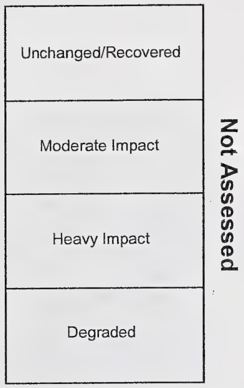


Natural Flows (1966 - 1995) No Recorded Flows

River: Waterton River
Reach: Headwaters
Consensus condition: n/a

Watershed Area (%): 562.0 km^2 (10%)
Streams – linear (density): 858.7 km (1.5)

Waterton River - Headwaters

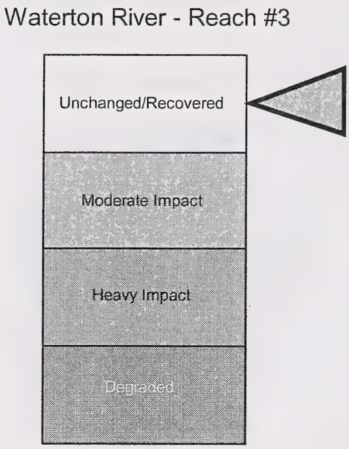


Issues:

1. The group of reaches above the road crossing (about 5 km south of Hatfield Hill) was not included in this assessment. The watershed includes much of Waterton National Park and the Waterton Lakes that lie within the park.
2. This section of river is used for some agriculture and forestry and comprises a significant portion of Waterton National Park.
3. The water quality monitoring data in this watershed (except for BL-01) are more than 10 years old.
4. Limited water extraction.
5. Key species identified as cottonwoods and bull trout.
6. Exotics identified as leafy spurge and brook trout, which are seen as jeopardizing native bull trout.

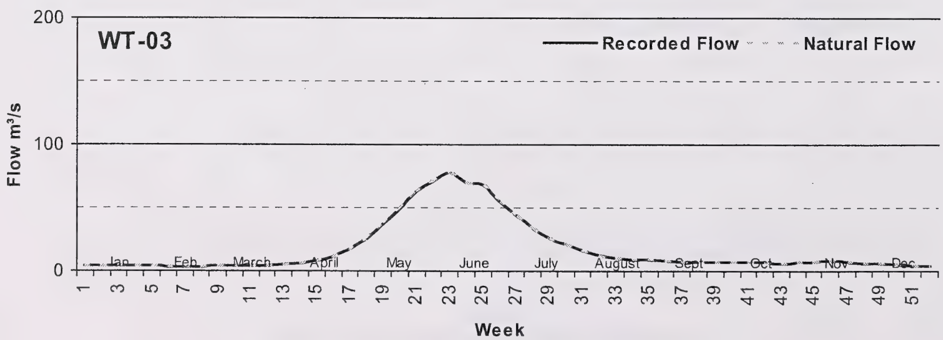
River: Waterton River
Reach: No. 3
Consensus condition: Unchanged / Recovered

Watershed Area (%): 485.2 km^2 (9%)
Streams – linear (density): 760.4 km (1.6)



Issues:

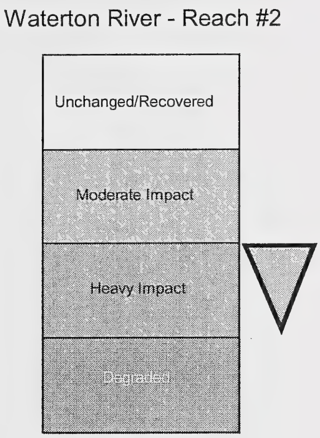
1. This reach includes the Waterton River from the road crossing (about 5 km south of Hatfield Hill) about 12 km downstream to the Waterton Dam.
2. A major source of water is sent from the Waterton system to the Belly River and eventually via a canal to the St. Mary Reservoir to the east.
3. As the water extraction is at the lower end of this reach, the flow is still intact and this was considered to be a reasonable reference reach.
4. Key species in all reaches includes cottonwoods. The key fish species is bull trout.
5. Exotics identified as leafy spurge and brook trout, which are seen as jeopardizing native bull trout.



Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

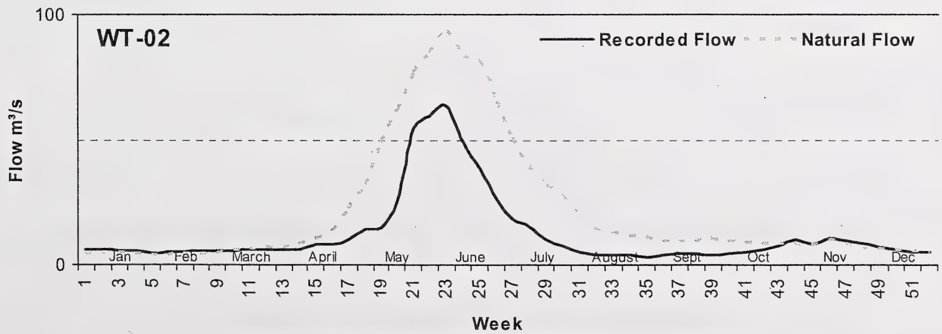
River: Waterton River
Reach: No. 2
Consensus condition: Heavy Impact

Watershed Area (%): 366.3 km^2 (6%)
Streams – linear (density): 523.0 km (1.4)



Issues:

1. This reach includes the Waterton River from the Waterton Dam to a point 45 km upstream of the confluence with the Belly River.
2. These lower two reaches were separated on the basis of channel morphology.
3. Sediment collection in the reservoir has established a new equilibrium downstream; sediment transport is now inadequate to maintain channel processes.
4. Minimum dam release is about 2.75 m^3/s.
5. Low flows and the resulting shallow water are significantly affecting water temperature resulting in a shift from coldwater fish species to coolwater fish species.
6. Bull trout are incidental in WT-02 and WT-01 (those that survive passage through the dam are reproductively dead as there is no area in which to spawn).
7. Key species in all reaches include cottonwoods, which are in decline in this reach. Key fish species are mountain whitefish and rainbow trout.
8. Exotics identified as leafy spurge.

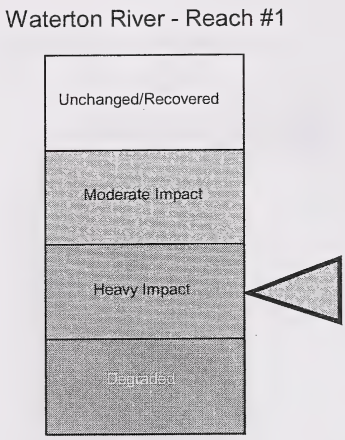


Natural Flows (1966 - 1995) Recorded Flows (1979 - 1997)

Note: Recorded flows are from gauge 05AD026 and the outflows from Waterton Dam.

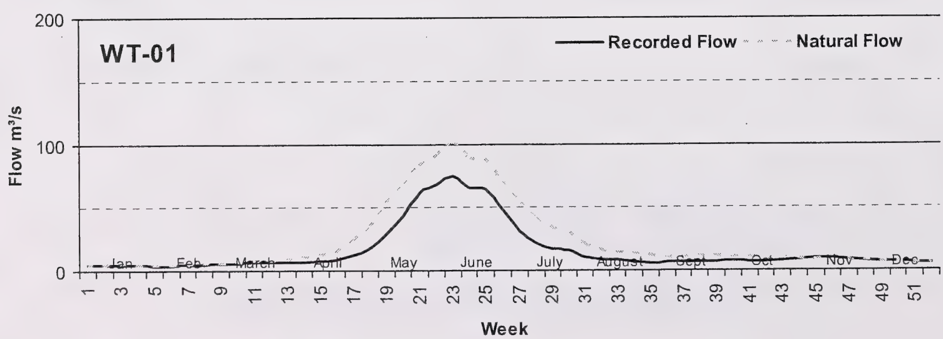
River: Waterton River
Reach: No. 1
Consensus condition: Heavy Impact

Watershed Area (%): 108.0 km^2 (2%)
Streams – linear (density): 175.9 km (1.6)



Issues:

1. This reach includes the Waterton River from a point 45 km upstream of the confluence with the Belly River to the confluence.
2. These lower two reaches of the Waterton River were separated on the basis of channel morphology.
3. Sediment collection in the reservoir has established a new equilibrium downstream; sediment transport is now inadequate to maintain channel processes.
4. Minimum dam release is about 2.75 m^3/s.
5. Reduced flood peaks.
6. Low flows and shallow water have significantly raised water temperature resulting in a shift from coldwater fish species to coolwater fish species.
7. Bull trout seen incidentally in this reach (those surviving passage through the dam have no area to spawn).



Natural Flows (1966 - 1995) Recorded Flows (1966 - 1995)

Note: Recorded flows are the combined flow of gauges 05AD008 and 05AD028.

8. Key species in all reaches includes cottonwoods, which are in decline in this reach. Key fish species are mountain whitefish and rainbow trout.
9. Exotics identified as leafy spurge.

Knowledge Gaps Identified in the Assessment of the Southern Tributaries of the Oldman River sub-basin

1. Studies required (ranked by importance: water #1, nutrients #2, sediments #3):
   - river regime studies (channel morphology studies below dam/diversions);
   - water quality database on tributaries is sparse and dated, needs improvement;
   - temperature monitoring needs expansion; and,
   - sediment loads need monitoring and study as to impacts.
2. Benthic invertebrate surveys are required.
3. Fisheries inventories (electrofishing) need to be updated.
4. Gas bubble disease (gas supersaturation) at the Belly Chute needs to be investigated.
5. Monitoring for exotics: zebra mussels, New Zealand snails, and Eurasian milfoil in the reservoirs (early detection and control).
6. Return flow in Pothole Creek should be investigated to determine if it may have a significant adverse influence on water quality.

APPENDIX VIII

SCIENTIFIC AND COMMON NAMES USED IN TEXT

The following list provides the common and scientific names for identification for plants and animals mentioned in the text of this report.

Common Name	**Scientific Name**
lake sturgeon (vulnerable status)	*Acipenser fulvescens*
St. Mary sculpin	*Cottus sp.*
goldeye	*Hiodon alosoides*
mountain whitefish	*Prosopium williamsoni*
rainbow trout	*Oncorhynchus mykiss*
brown trout	*Salmo trutta*
brook trout	*Salvelinus fontinalis*
bull trout	*Salvelinus confluentus*
sauger	*Stizostedion canadensis*
walleye	*Stizostedion vitreum*
clams (zebra mussel)	*Dreissena polymorpha*
New Zealand mud snail	*Potamopyrgus antipodarum*
midges	Chironomidae (pollution tolerant)
mayflies	Ephemeroptera (pollution sensitive)
worms	Oligochaetae (pollution tolerant)
stoneflies	Plecoptera (pollution sensitive)
cottonwood	*Populus balsamifera*
willow	*Salix spp.*
smooth brome grass	*Bromus inermis*
Canada thistle	*Cirsium arvense*
Russian olive	*Elaeagnus angustifolia*
leafy spurge	*Euphorbia esula*
purple loosestrife	*Lythrum salicaria*
alfalfa	*Medicago sativa*
Eurasian milfoil	*Myriophyllum spicatum*
Kentucky bluegrass	*Poa pratensis*

APPENDIX IX

BIBLIOGRAPHY / READING LIST

This reading list was derived from the participants of the Sub-basin Technical Workshops. Each participant was asked to provide a list of what they considered the five best reports related to their sub-basin and to the general topic of assessment of ecological condition of rivers. Although the editors have tried to standardize the format and style, the original documents have not been available and thus error checking has been somewhat limited.

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